JANUARY 1960 • VOL. 16, NO. 1

SPE JOURNAL

The Official Publication of the Society of Plastics Engineers, Inc.

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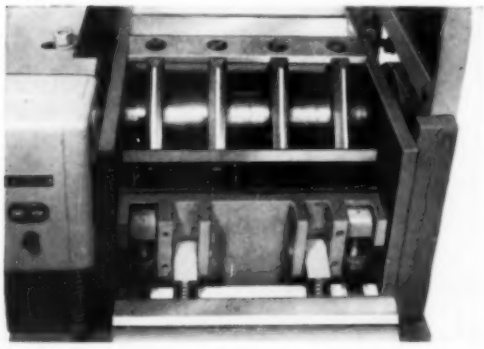

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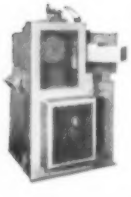

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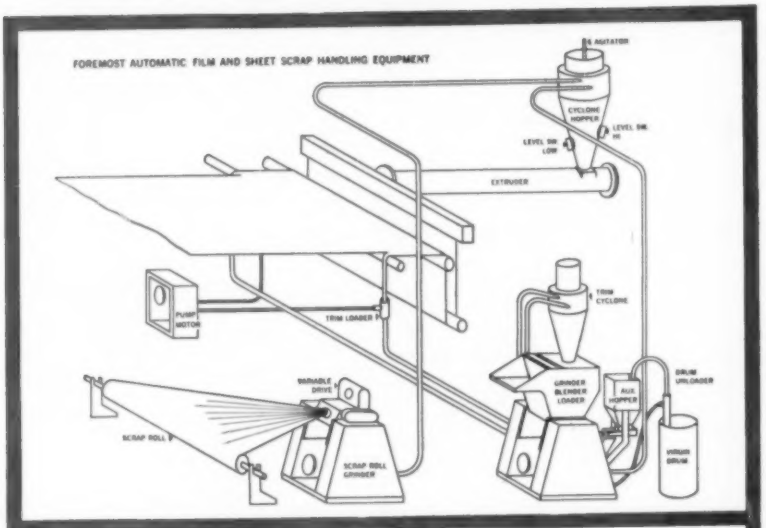

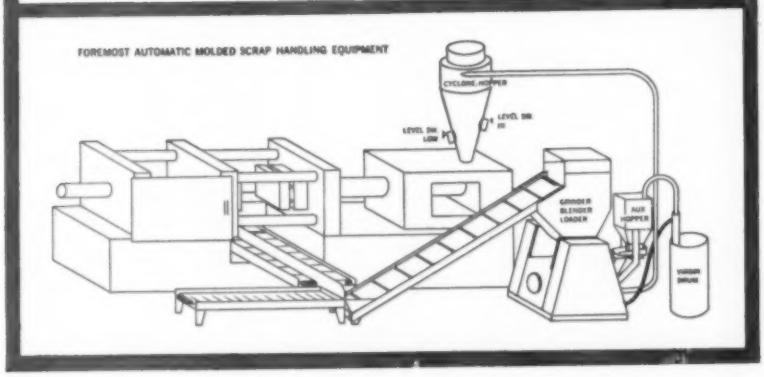

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SPE JOURNAL

plastics engineering trends of technical *significance*

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This article carries the discussion above one step further, and provides a detailed example of how quality control data must be expanded to permit screening of materials over a wider range of measurements.

THREE-DIMENSIONAL ANALYSIS

The use of three-dimensional analysis of plastics materials data is shown. The article explains the function of this method as a design tool in determining the full potential value of a plastic under consideration.

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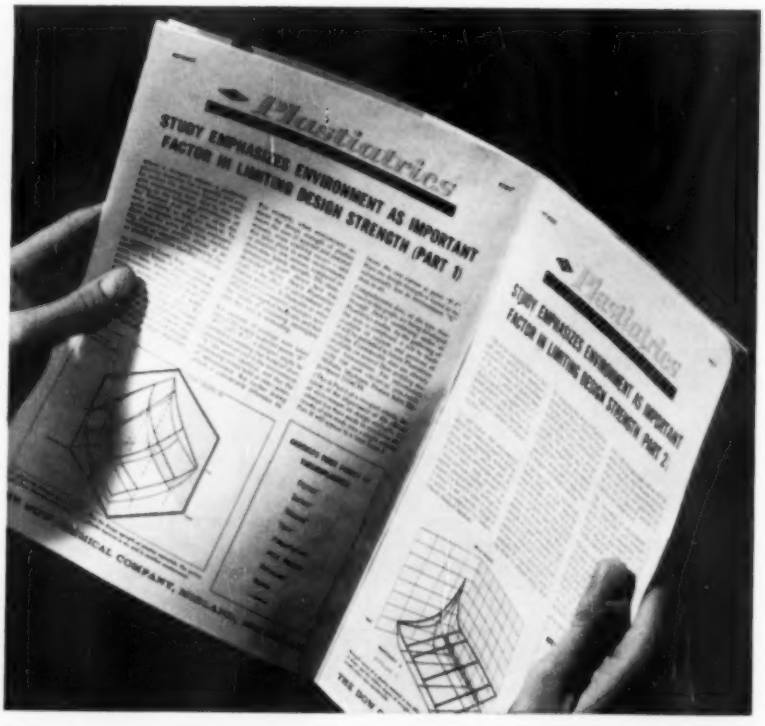
This two-part article describes the variable effect of environment on the working strength of plastics materials, and the necessity of testing under the environmental conditions to be encountered during actual use of the finished product.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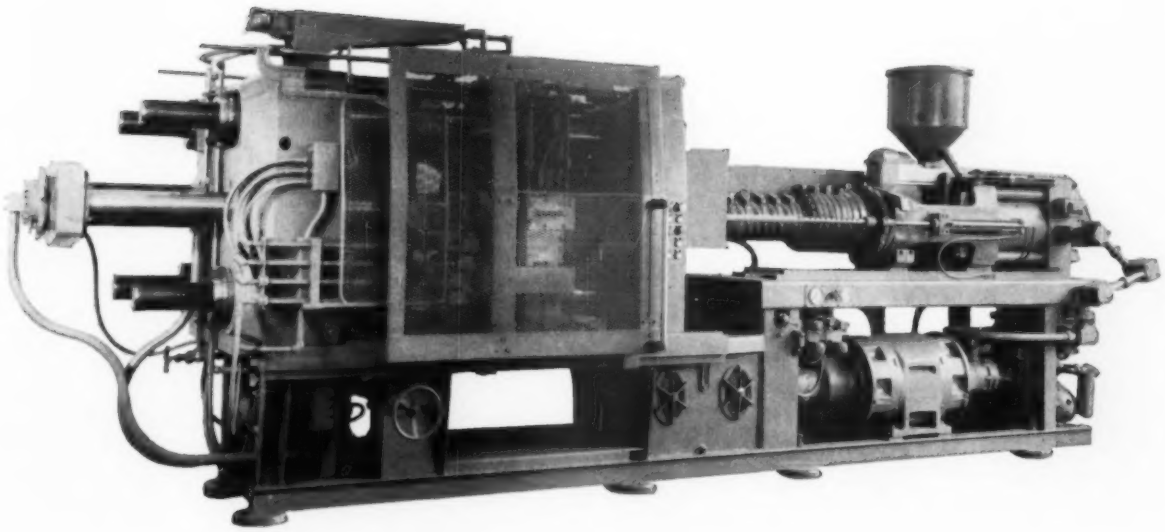

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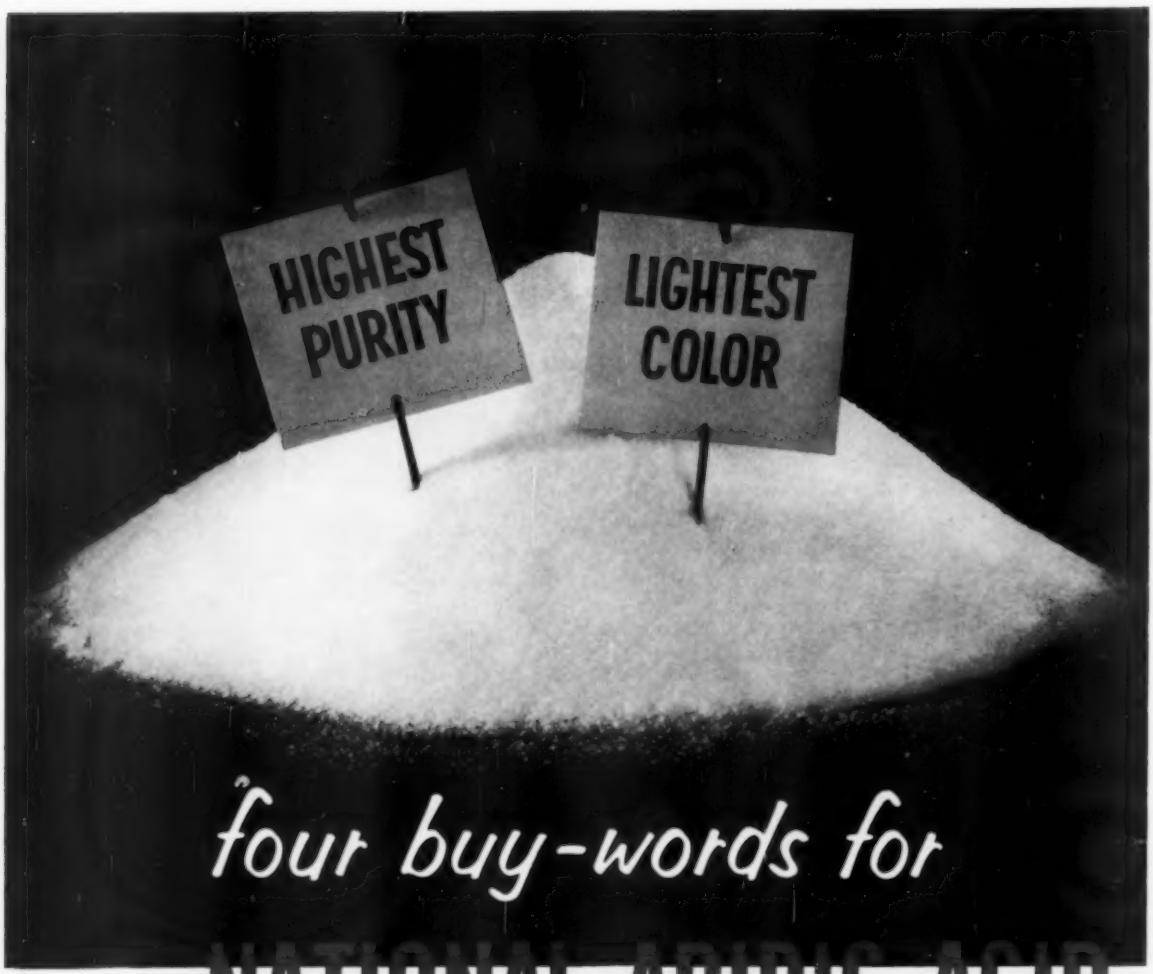

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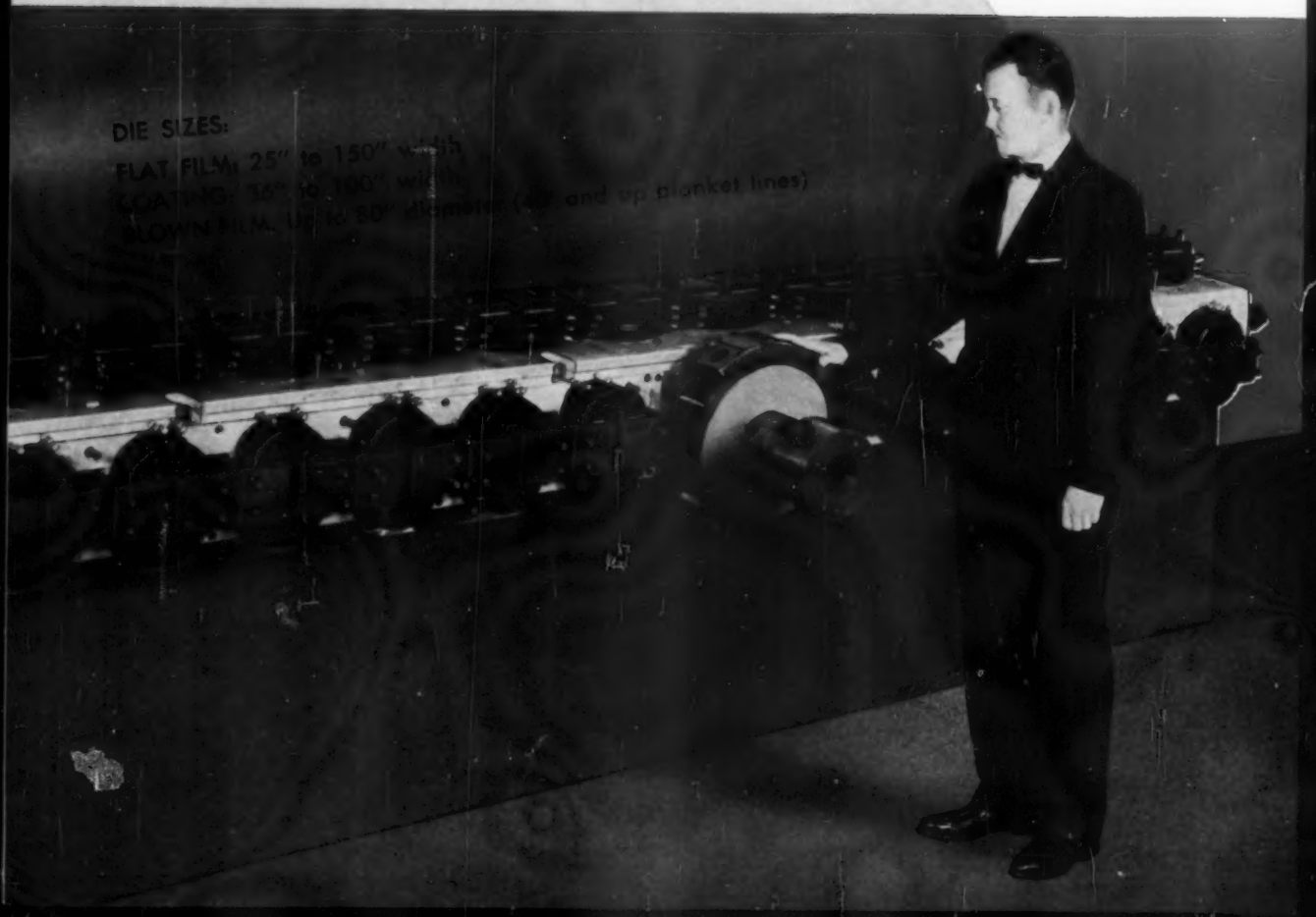

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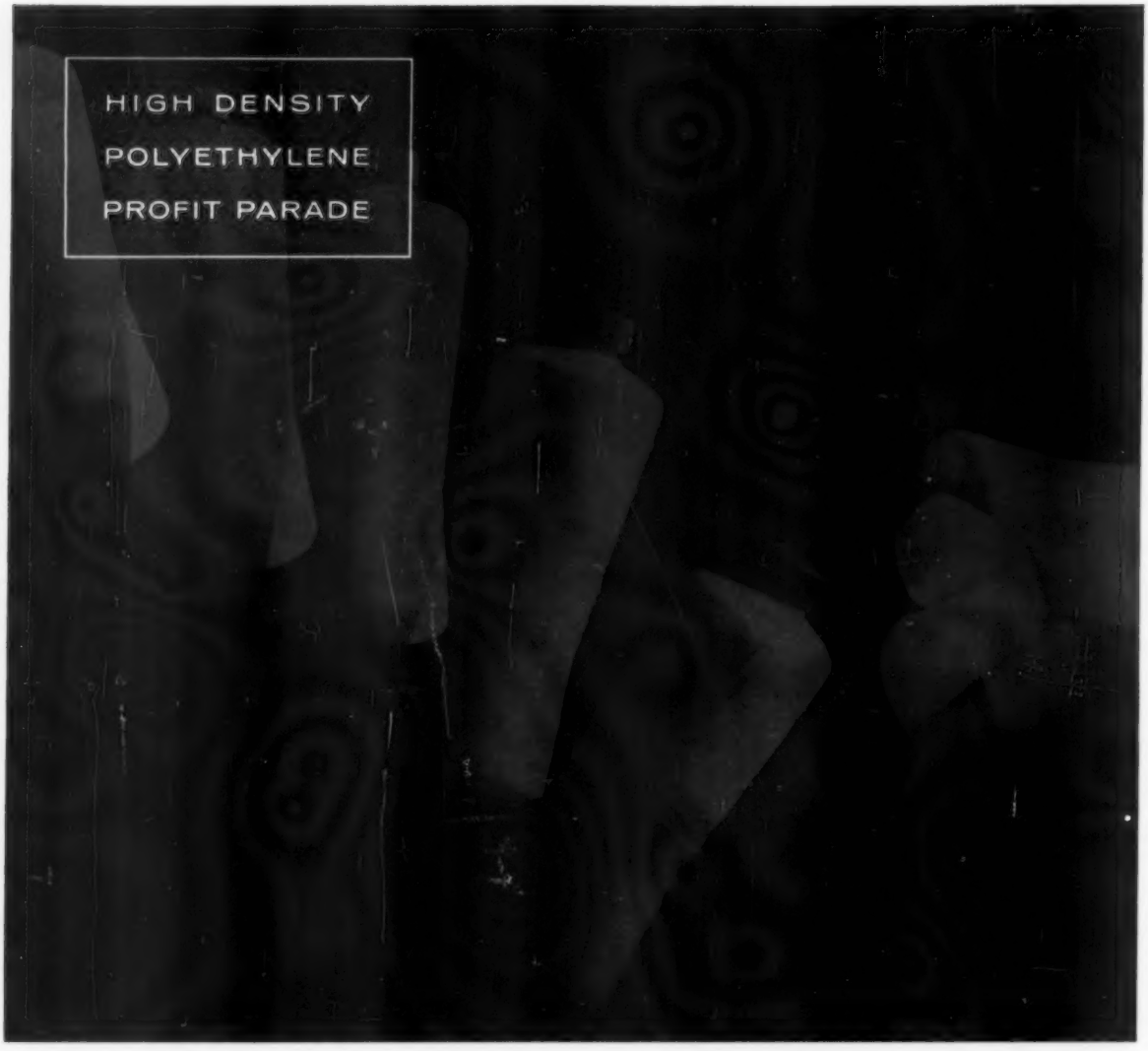

Plastics Development Pays Off for Hollow Products

If hollow products, parts or containers are important in your business you should know what blow molding and high density polyethylene from Grace have to offer. These dent-resistant, durable bottles by Owens-Illinois show a few of the benefits never before realized with other plastics and fabricating techniques.

High density polyethylene can be used to produce hollow objects such as these bottles that are featherweight yet remarkably rigid and strong, even in thin wall sections. Economies in production and raw materials naturally follow. In addition, these bottles are resistant to abrasion and virtually indestructible. They withstand refrigeration without cracking, autoclaving without distortion and exposure to most chemicals. Significantly, the Owens-Illinois no-drip bottles are comparable in cost with many of today's packages.

Blow molding also permits the use of Grex resins that result in superior strain-free characteristics, often difficult to achieve by other techniques.

Sound interesting in terms of the products you make? Then you'll also be pleased with the surprisingly low mold costs, too. For the full story on this versatile plastics development call in the high density polyethylene experts. Grace has the production facilities, technical service and experience to help put your product in the Grex profit parade. Everyone says we're easy to do business with.

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EDITORIAL

On the Horizon

January usually signals the beginning of bigger and better things to come in the new year. So, too, the January issue of the SPE Journal, featuring a new look, signals the beginning of a year with a number of new features and expanded editorial scope.

Most significant of the changes in this new year is the cover. A shortened name—The SPE Journal—and revised cover format will allow greater flexibility in future cover designs and make possible more attractive covers.

The brand new SPE Journal Newsletter begins on page 17. It differs from other newsletters in that accent is placed on new technical developments—**ideas that you can use**—not just interesting information of passing interest.

Another first—starting in the February issue will be a new Journal feature. Its title: Plastics Standards. Its Editor: Dr. Frank W. Reinhart, National Bureau of Standards. The need has long been there. The SPE Journal will fill that need. This feature will carry information of new standards of products, testing methods, and materials in the field of plastics.

To keep up with the rapid growth of the plastics industry, the SPE Journal this year will feature a widened editorial scope. Special features of interest to a wide spectrum of the Journal's readers—yet in specific areas—are now in the preparation stage and will appear in forthcoming issues.

Starting early this year the SPE Journal's technical manuscript reviewing system will be greatly expanded. Members of the Editorial Advisory Board will head up groups of reviewers working in specialized fields, the liaison to be accomplished through SPE's Professional Activities Groups. This expanded reviewing system will result in papers of the highest quality being published in the Journal and also articles that represent the latest, up-to-the-minute information in their fields.

Blow molding with Grex offers fabricating economies and new product possibilities.

Blow molding is today's fastest growing fabricating technique—and no plastics lend themselves to blow molding better than high density polyethylene. This holds true whether the application is as straightforward as these Owens-Illinois bottles, or as complex as toy cars large enough to hold a child. Here are a few reasons behind the boom in blow molding with high density polyethylene:

Savings in mold and equipment costs. Because of the low pressures involved in fabricating Grex by this technique, lightweight molds can be made of easily toolable materials. Thus mold costs are $\frac{1}{6}$ to $\frac{1}{5}$ less than for any other fabricating method. Furthermore, blow molding is a simplified technique, often adaptable to existing injection molding and extrusion equipment.

Economies in resin requirements and cycle times. The physical properties of Grex (rigidity, heat distortion resistance, abrasion resistance) permit blow molding of thin wall sections. As a result, less resin is used per molded piece. Cycle time—even for large parts—is also reduced. Cycles in blow molding are limited only by the time it takes to cool a part. Thinner walls made possible by the characteristics of high density polyethylene speed cooling and cut cycles.

Ease of molding. Complex shapes with serious undercuts, often difficult to blow mold with other plastics, rarely present problems when a Grex blow molding resin is specified. In fact, fabricators find this technique permits use of resins having superior physical properties without sacrificing moldability. Also inherent in blow molding is the fact that costly assembly operations are held to a minimum. The large toy car, for example, is blown in a single piece.

Find out more. If you have an application for blow molding with high density polyethylene—or think you have—count on Grace for help. Write now to:

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MODELS* 6P . . . . for up to 2" Extruders
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They handle all thermoplastic materials, even elastomerics.

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Provision is made for the discharge of longs, independent of perfect pellets.

Provision is also made for an air- or water-cooling connection for the pellets.

For further details and prices on the machine more and more plastics compounders and virgin material manufacturers are ordering, write or call your nearest Alsteele representative today.

*Available in mild or stainless steel

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Two completely independent systems . . . each with its own heater, pump and controls. Model 6007 accurately will maintain two different temperatures simultaneously.

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High Temperature Control Units

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Model 6016
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Provides one temperature range. Where desired, three 6016 units may be mounted on a single base to maintain three separate temperature zones.

These two Sterlco units are designed to maintain extremely high temperatures accurately and safely. Heat transfer fluids are circulated at low pressure! Electric immersion heater of 12 KW capacity, and 10 G.P.M. circulating pump, are standard. However, heaters of 18 KW and 24 KW, and 18 G.P.M. circulating pumps are optional. Provisions for cooling also available.

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Sterlco field engineers and engineering staff are available to help solve your temperature control problems. Write us today.

Leaders in temperature control since 1916

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Industrial Control Division

SYMBOL OF PROFESSIONAL EMINENCE

New Lapel Pins Available

SPE pins of new design and material can now be obtained from the SPE National Office. The pin is die-molded of zinc in the design shown in the illustration. The SPE red is in baked enamel finish and the letters and margin are provided by the gold of the die casting showing through.

In approving the new material and design, the Membership Committee emphasized that both the plastic pin, distributed previously, and the new die-molded zinc pins are official SPE pins. The zinc pin does *not* supersede the plastic pin.

The new pins are mailed gratis to all new members admitted to the Society since the supply of plastic pins became exhausted.

To Sections and other SPE members they may be purchased postpaid from the SPE National Office, 65 Prospect Street, Stamford, Conn., as follows:

No. of Pins	Price
1-24	$1.00 each
25 and more	.75 each

All orders must contain remittance.

reading time
1 minute

Printing on Polyethylene

A new instrument makes possible the rapid measurement of the printability of polyethylene surfaces. Developed by T. F. McLaughlin of Du Pont, the instrument measures angles of inclination at which uniform drops of distilled water slide from treated surfaces. These angles correlate with the printability of the surfaces . . . The RETEC, Stability of Plastics, sponsored by the Baltimore-Washington Section of SPE on December 1, 1959, accomplished what may be termed a "perfect marriage" of basic and applied technology. Basic polymer technology of vital interest to the applied plastics engineer was combined in one program. The RETEC was a great success, and should spark similar ideas in other Sections . . .

60 pounds of plastics in every car

Food for thought: The average new car in the U. S. will use about 20 pounds of plastics parts, but study of functional applications shows that over 60 pounds could be used . . .

"iron" adhesion for PVC

How to bond PVC films to synthetic fabrics is a problem. A new primer coat just developed may be the answer. The formula: Vinyl chloride, vinyl acetate, maleic anhydride terpolymer—100 parts, dioctyl phthalate—40 parts, methyl ethyl ketone—200 parts, and dianisidine diisocyanate—10 parts . . . Ever thought of painting instead of molding in color? The article on page 84, this issue, may interest you, then. Painting is more economical where a large variety of colors is desired and the quantity produced is low . . .

cookies in cartons

A new twist. Sheet plastic is being formed into packages without the application of heat or adhesives. It is the result of a new machine which cold-folds and locks unscored die-cut plastic blanks into trays at speeds of 40 to 100 a minute, depending on size. Already nine major carton manufacturing plants have been licensed to produce and supply plastic blanks for the machine.

Heels molded of Tenite plastics have a natural "patent leather look"

TENITE

ACETATE • BUTYRATE

Eastman plastics for shoe heels

Tenite Acetate and Tenite Butyrate were the first plastics used in volume to replace wood for heels.

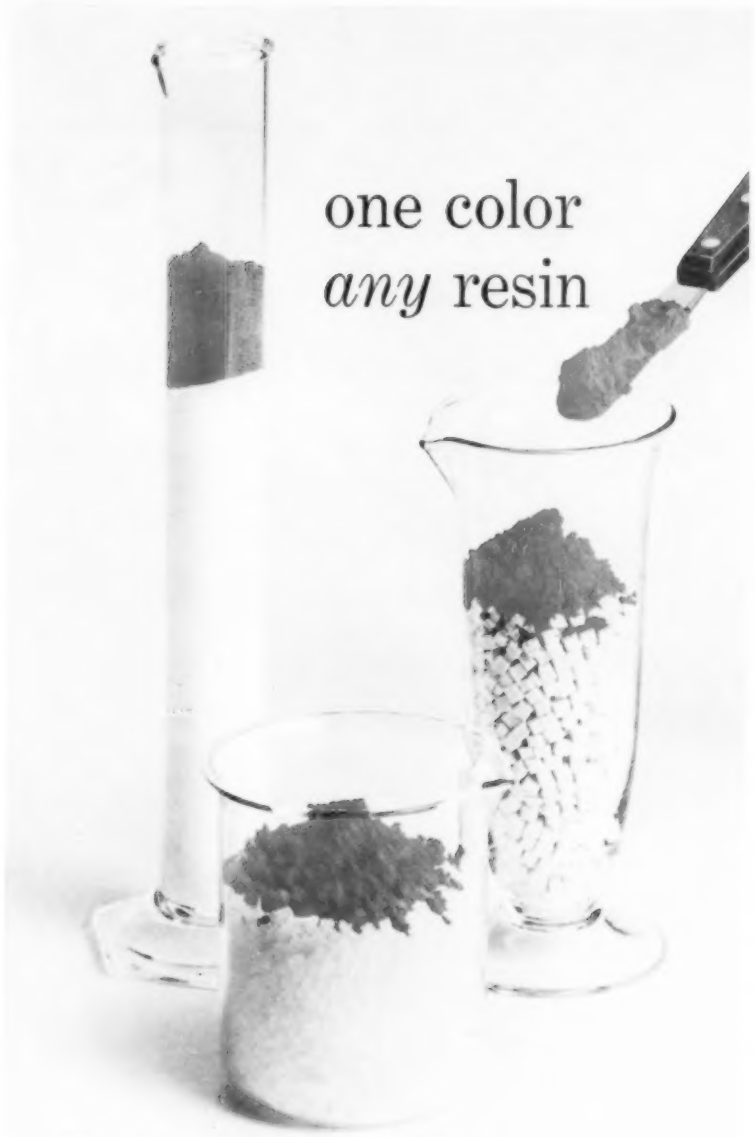
The strength of these plastics far exceeds that of wood and markedly reduces breakage of heels during manufacturing, wearing or cobbling. Extremely versatile in finishing operations, they can be used "as molded," sprayed with lacquer, metallized, or covered with plastic, leather or fabric.

Today, many shoe manufacturers are taking advantage of the natural high gloss of these plastics and are standardizing on black Acetate heels or black Butyrate heels for patent leather footwear.

Requiring no spraying or covering, black* heels made of these Tenite plastics are perfect mates for patent leather shoes. With no surface coating or covering to peel off, they can withstand unusually hard wear without showing scuff marks. EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

***** *While black usually is synonymous with patent leather, these Tenite plastics also are available in any other desired color, including clear-transparent.*

Shoes by **Ornsteen Shoe Company,** Haverhill, Mass. Heels finished by **Wm. Ornsteen Heel Co., Inc.,** Haverhill, Mass. Heels molded by **Ace Plastics Corp.,** Bradford, Mass.



Ferro dry colors

Here's the lowest cost, easiest way to get colored resins. Buy them *uncolored* and color them yourself with Ferro high-fidelity dry colors.

Uncolored resins cost less. You color only what is needed for the job. This reduces inventory, blocks waste, saves time on rush jobs. No special equipment is needed.

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Color Division

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Robert D. Forger

NEW NATIONAL OFFICE STAFF ASSISTANT

On December first Robert D. Forger joined the SPE National Office Staff as an Administrative Assistant. His major responsibilities will be to assist Section Officers and Boards in organizing and operating their Sections; to implement the Society's public relations program; and to provide staff assistance to ANTEC, NATEC, and RETEC Committees on meetings. His first assignments are to work with the Sections Committee in editing and completing the Section Procedures Manual and to aid the 16th ANTEC Publicity Committee in Chicago.

Mr. Forger graduated from Norwich University in 1949 with a B.S. in Chemistry. He was on the staff of Dorr-Oliver Inc. in Stamford for over ten years as a research and development engineer, in their advertising and public relations departments, and as Manager of Technical Publicity. A resident and native of Westport, Connecticut, he currently serves as Chairman of that town's Housing Authority and is also active in the U.S. Army Reserve.

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2. **BROADEN YOUR PROFESSIONAL CONTACTS**
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   by contributions to technical programs and publications.

4. **DEVELOP YOUR ADMINISTRATIVE CAPABILITIES**
   by service on Section and National levels.

5. **ESTABLISH LASTING FRIENDSHIPS**
   with individuals having common interests and engaged in similar work.

Why not investigate membership today with local Section Officers; the SPE National Office at 65 Prospect Street, Stamford, Connecticut; or in Chicago at the ANTEC Registration Desk?

AVISUN

The full distribution facilities of the Shulman organization are now ready to supply you with AVISUN POLYPROPYLENE molding and extrusion resins. Strategically rotated warehouses assure quick delivery to any point in the nation. In addition, through A. Shulman Inc., Avisun technologists are at your call to assist you in exploring present or anticipated product applications for this exciting new material.

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Hubley Tic Toy Clock—many of the 40 parts are made on The Lampeter Manufacturing Company's Van Dorns.

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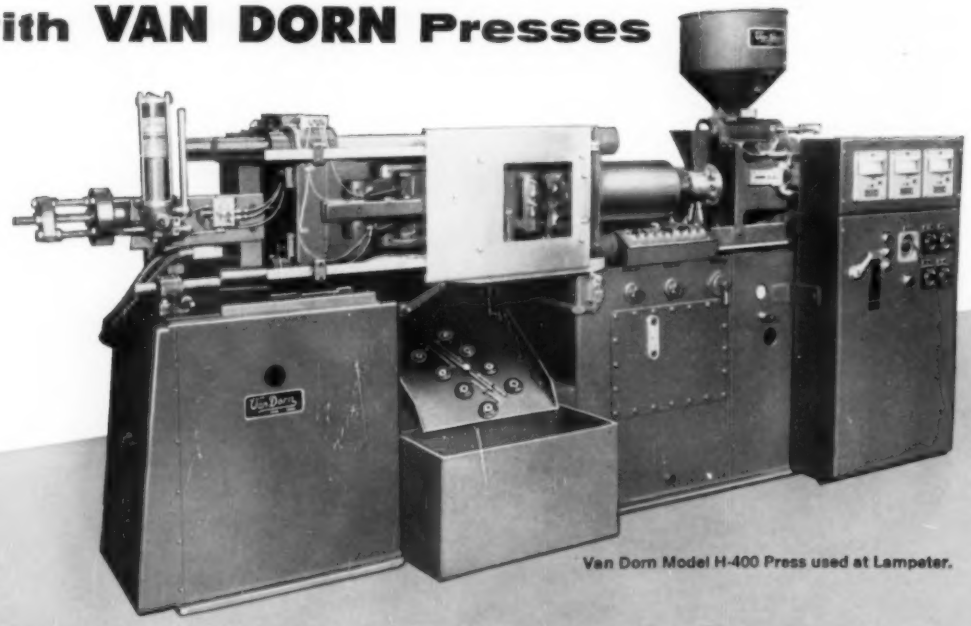
AUTOMATION

with VAN DORN Presses



Van Dorn Model H-400 Press used at Lampeter.

As a major supplier for The Hubley Manufacturing Company, a leading toy producer, The Lampeter Manufacturing Company is an extensive user of plastic machinery. Lampeter operates their fully automatic Van Dorn 4-6 oz. and Van Dorn 3 oz. presses *24 hours a day, six days per week.*

Besides a substantial reduction of cycle time, the company reports the Van Dorn presses are economical, versatile, and require minimum maintenance. The general manager says that if he buys more machines of the same size, Van Dorns would certainly be a top consideration.

You, too, can save time and money with Van Dorn high production injection presses. Write for detailed information.

Inspection of toy parts produced on the Van Dorn H-300.

Van Dorn

THE VAN DORN IRON WORKS CO.
2685 East 79th Street • Cleveland 4, Ohio

U.S.I. POLYETHYLENE NEWS

A series for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

SUMMER, 1959 U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation 99 Park Ave., N. Y. 16, N. Y.

Packaging Notes

Throw-away Polyethylene Pillow Covers are now being manufactured for use in hospitals.

The strong, lightweight, polyethylene

Disposable polyethylene pillow covers for hospital use are convenient, easy to handle, help prevent cross infection.

covers are easy to handle... are disposed of when the cover is changed. The Manufacturer reports the pillow slips reduce danger of cross infection, eliminate autoclaving and help avoid waste. In addition, the slips may be used as disposable containers for contaminated objects. The manufacturer packages the product in pop-up dispensers containing 500 covers.

Polyethylene Bag-in-Box Packaging has significantly lowered shipping costs and improved the efficiency of a mid-western creamery.

The company reports it now ships 50 to 55-lb. containers of dairy products in 3-mil polyethylene bags packed in corrugated cartons in place of previously used returnable 10-gal. cans. Use of polyethylene helped cut shipping and maintenance costs by 17%, and saved valuable storage space necessary for the metal cans.

Further benefits are: greater control over package weight, shelf-life of products is doubled, insect infestation is eliminated, and leakers are greatly reduced.

Bags are made from polyethylene tubing which are completely heat-sealed across top and bottom except for a 5-inch opening at one corner. The bags are filled through the opening which is then tied shut with tinned wire. A shipping line speed of 125 to 150 bag-in-box units per hour is reported.

Polyethylene Wins Awards In Packaging Competition

Packages consisting in whole or part of polyethylene won six of the top awards in the recent National Flexible Packaging Association competition. Awards were presented during the fall meeting of the NFPA at White Sulphur Springs, West Virginia.

First prize in the "Break-Through" category went to a food concern for a polyethylene-coated bag for a line of fruit-flavored "icicles". Among the other winners using polyethylene as a film, laminate, or coating were bags for: water softener, hybrid corn seed, potatoes, marshmallows, and a polyethylene wrapping for bread.

U.S.I. Forms International Company To Serve Polyethylene Markets Overseas

New Unit Will Provide Technical Service, Sales, and Market Information

A new European company has been formed by U.S.I. to handle the overseas sales of PETROTHENE polyethylene resins and to provide technical service to customers and help in developing markets for polyethylene products. The new unit will be called U. S. Industrial Chemicals Company-International, Division of Sales and Development Company of National Distillers and Chemical Corporation (International) S. A., located at Kirchenstrasse 13, Zug, Switzerland. Operations of the new subsidiary began during October of 1959.

Howard W. Woodham

Kenneth E. Cosslett

Well Equipped Facilities

A customer service laboratory will be an integral part of the new company. It will be completely equipped with processing and test equipment designed to meet European standards and operating conditions. The laboratory will be used to demonstrate processing techniques and for research and evaluation studies to help its customers develop new end-use markets and produce improved products. The laboratory will also include polymer testing equipment to insure product quality. The laboratory will service markets in the European countries, including the United Kingdom. Howard W. Woodham is the Manager of the new Technical Service Laboratory.

To Back Up Local Agents

Sales Manager of U.S.I.-International is Kenneth E. Cosslett, who has been U.S.I.'s Assistant Export Manager. According to Mr. Cosslett, U.S.I.-International's PETROTHENE resin sales will be made through its established representatives in European countries. The new company will be a supporting unit to help these representatives provide the close technical assistance which the polyethylene market demands.

Nuclear Reactors Use Polyethylene Plate

Polyethylene plate is used in nuclear reactors as a replacement for concrete in areas where weight and space limitations are of primary importance. Polyethylene plate exhibits excellent neutron-shielding capacity and is widely used for neutron-shielding protection on nuclear reactors.

Automatic equipment for uninterrupted extrusion of polyethylene plate is now producing 48-by-96-inch sheets of the plate at a rate of 6,000,000 pounds per year. It is extruded in thicknesses up to 1½ inches from PETROTHENE 100 resins in both natural and specially compounded forms.

Critical properties of the polyethylene plate produced by the continuous extrusion process are reported to be equal to or exceed those of plating produced by compression molding methods. The chief advantages of forming polyethylene plate by extrusion are a high rate of production and guaranteed freedom from voids.

Duck Hunters Use Polyethylene Film

Duck "ponds" of polyethylene film are being used by a number of hunters throughout the country.

Photo courtesy True, The Man's Magazine

The novel man-made "ponds" are built by spreading polyethylene film in fields where ducks feed on their southward journey each fall. The sun's rays reflect from the polyethylene film which appears to be open water in a frozen field. A spread of decoys further heightens the illusion.

Hunters say by the time ducks realize their mistake, it's usually too late!

DO YOU HAVE a new polyethylene packaging development you'd like the industry to know about? Make it routine to send your information on new developments to U.S.I. POLYETHYLENE NEWS.

Address the Editor,
U.S.I. POLYETHYLENE NEWS, U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corp., 99 Park Avenue, New York 16, N. Y.

U.S.I.
Vol. V, No. 1

POLYETHYLENE PROCESSING TIPS

CONTROL STOCK TEMPERATURE TO IMPROVE FILM PROPERTIES

Polymer or "stock" temperature is one of the most important variables in extruding polyethylene. Fluctuating polymer temperatures can cause undesirable variations in film properties and operating conditions.

With blown film, for example, poor temperature control may result in such film defects as non-uniform gauge, width fluctuation, variable optical properties, wrinkles in the finished roll, pinholes, and bubble rupture or collapse during extrusion.

Determining Optimum Temperature

The effect of stock temperature on three important film properties – haze, gloss and transparency – is shown in the accompanying graph. Within the temperature range necessary to maintain a bubble, increasing stock temperature results in improved optical properties. The optimum stock temperature, from an optical standpoint is, therefore, the maximum temperature at which a uniform bubble can be maintained.

When the optimum stock temperature is determined for a particular set of conditions, it must be held constant. Any lowering will cause deterioration in optical properties, and any increase will result in poor bubble control and eventually in bubble collapse.

How the Resin Is Heated

Stock temperature is maintained by two heat sources:

1. Uncontrolled heat produced by the action of pressure and friction within the extruder barrel. This is the primary heat source.
2. Controlled heat supplied generally by an external electrical heating system. This is the secondary heat supply.

The electrical heating system used in most extrusion operations consists of a heat source (resistance heaters), a number of thermocouples to sense the temperature of the barrel wall, and temperature-indicating devices such as deflection-type galvanometers or potentiometers. The potentiometer, which measures the voltage supplied to the heater, is more sensitive than the galvanometer, which measures the current passing through the resistance wire. However, since galvanometers are less expensive, they are in more common use.

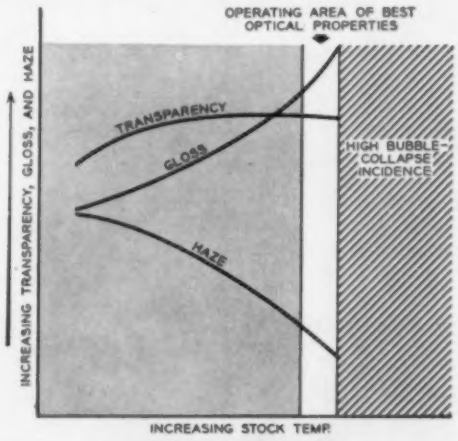
Controlling Temperature

Heaters should fit snugly against the barrel surfaces to insure good heat transfer. Loose heaters will result in loss of heat as well as uneven heating.

When a thermocouple needs changing, it is important to replace it with one of the same length and composition. Galvanometer-type temperature indicators are calibrated for a specific amount of external resistance, including that of the thermocouple. If a thermocouple of different lead length and composition is used as a replacement, the galvanometer must be re-calibrated accordingly.

The primary heat produced by action within the extruder barrel increases with operating time. This is the result of screen pack contamination, with attendant build-up of pressure and friction.

Unless this additional heat is compensated for, stock temperatures will rise although the thermocouple and galvanometer settings are unchanged. The external heating controls do not respond because the temperature of the wall measured by the thermocouple differs from the actual temperature of the resin melt itself. However, lowering the thermocouple settings will reduce the heat input from the external heaters and will tend to offset this additional internal heat and keep stock temperature constant.



Accurate Melt Temperature

The operator can obtain a better indication of actual melt temperature by means of a thermocouple which extends through the die or collar wall into the melt stream. He can also attach a simple pressure gauge to the extruder barrel (see U.S.I. Polyethylene Processing Tips, Vol. IV, No. 5). This gives a constant check on internal pressures affecting polymer temperature.

For good temperature control it is necessary to recognize a difference between actual stock temperature and measured temperature; this temperature difference increases as pressure goes up. Using experience as a guide, the operator can make periodic adjustments of control temperature to keep actual polymer temperature constant.

The effect of stock temperature on film properties is vital, and a variety of problems may turn up in connection with efforts to keep the optimum temperature constant. We, therefore, invite you to ask for the cooperation of U.S.I. Technical Service Engineers whenever control problems arise.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
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epoxy fan blades up to 14 feet in diameter

Tuf-Lite epoxy fan blades for cooling tower, heat exchanger, and ventilating fans have a combination of toughness and high strength that permits diameters up to 14 feet! And the TONOX hardener which helps give these Hudson Engineering blades their unusual properties is relatively low in cost. (Actually costs less than the epoxy it replaces!)

Formed in a pressure-bag molding operation and cured at 250°F., these lightweight, hollow blades are smooth surfaced, distortion free, able to withstand high heat, severe corrosive conditions, and the attacks of sand, rain, and hail.

Among the advantages TONOX offers are:

- unusual strength and impact resistance
- excellent chemical resistance
- good electrical properties
- good dimensional stability at temperatures as high as 285°F.
- easy mixing with liquid epoxy resins
- easy handling with freedom from irritation
- low cost

Try TONOX. Chances are you'll join the epoxy molders across the nation who rely on TONOX for the properties their products demand. Contact your Naugatuck Representative or write us for samples and full technical information.

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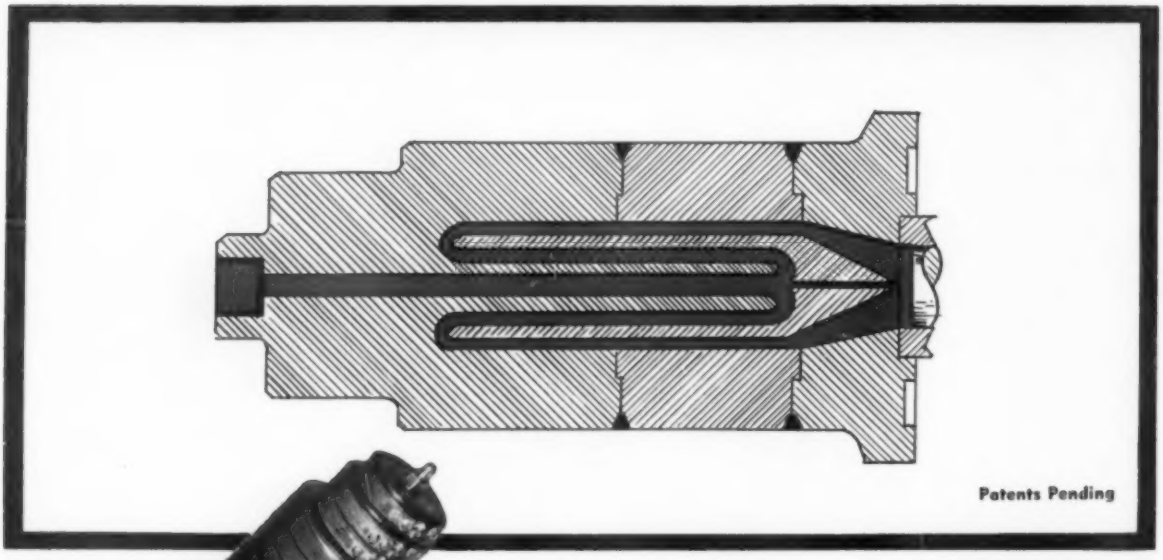
VRF Vented Reverse Flow Heaters



Patents Pending

Leading injection molders know— it's what happens INSIDE the heater that really counts!

Here's ultimate proof of IMS Leadership in heating cylinder design! The new exclusive VRF Degassing principle automatically overcomes many common molded-in defects. It's brought to you by the same cylinder engineers who pioneered the IMS Standard Uniform Design All-Welded Replacement Chamber in 1949. Note how the exclusive vent hole allows trapped, compressed gases to escape out of the melt area just prior to injection. This hot bleed-back speeds melting of cold granules, and often lowers pressure requirements by lubricating the spreader tip with soft plastic. You gain the advantages of precompression with no moving parts!

Cylinder corrosion on cellulosics is virtually eliminated by gas relief. Production time between clean-outs on Vinyl is greatly extended.

Pressure equalizing bleed-back gives automatic part weight control without a feed weigher.

VRF reduces burning because internal storage tube keeps material inventory away from heat source. Remember! It's what takes place INSIDE a heating cylinder that really counts!

IMS

SPECIAL PURPOSE REPLACEMENT HEATING CYLINDERS FOR ALL INJECTION MOLDING MACHINES.

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William T. Yost, *The American-Marietta Co. Newark, Ohio*

MOLDING CYCLES

Epoxy Molding Compounds

Conditions for molding one-package system epoxies

Epoxy molding compounds may be divided into two general types; the first mineral filled, the second fiber reinforced. The mineral filler may be clay, mica, silica, or in some cases highly filled with carbon or graphite. Loadings may vary from 40% to 85%, contingent upon the type of filler used. The fiber reinforced may be subdivided into two groups; organic materials, such as nylon, dacron, and acrylon, or inorganic, such as glass. For these compounds, the reinforcing may be 50% or more of either organic or inorganic fibers. The fiber reinforced may contain a portion of a mineral type filler.

There is a third variation to the two general types; a self-extinguishing group, which may be either mineral filled or fiber reinforced. This type is rather unique in that self-extinguishing property is gained by the use of a special epoxy resin. This new resin does not obtain its self-extinguishing characteristic from the liberation of chlorine, from additives to the resin, or from fillers.

The epoxy molding compounds may be either compression or transfer molded. Limiting factor in transfer molding is the amount of reinforcing fiber in the compound. Experience has shown that the maximum reinforcing will be in the range of 25% glass, or up to 30% organic fiber. The mineral filled and low fiber reinforcement present no difficulty.

General temperature recommendations for transfer molding are 265°F. ± 15°F. For compression molding, a temperature of 285°F. ± 15°F. is recommended. It should be noted that these are not hard and fast rules, but are work areas which have given the best results. Blistering has been noted in some cases when temperatures above 300°F. have been used. Epoxy does not out gas, blisters are due to either entrapped air or moisture.

Recommended pressure for transfer molding the non-reinforced material is 100 ± 25 psi. For the reinforced types with up to 25% reinforcing, transfer pressure up to 500 psi may be required. Material containing less than 15% inorganic fiber reinforcement has been transfer molded at 125 psi. These pressures are for powder loaded systems. Preforming and preheat may further reduce pressures.

Molding Requirements for Epoxies

Temperatures

- **Transfer—265°F., plus or minus 15°**
- **Compression—285°F., plus or minus 15°**

Pressures

- **Transfer—reinforced, less than 15%, 125 p.s.i. reinforced, up to 25%, up to 500 p.s.i. non-reinforced, 100 p.s.i.**
- **Compression fiber reinforced, up to 2000 p.s.i. non-reinforced, 100 p.s.i.**

For compression molding, epoxy compounds require pressures ranging from 100 psi for the non-reinforced type, to 2,000 psi for the highly reinforced cold powder materials. As in the case of transfer molding, preheated preforms reduce pressures required. For nylon and dacron fiber reinforced epoxy molding compounds, 1,500 psi should be the maximum pressure used. If higher pressures are used, segregation of fibers and mold sticking may occur.

No special molds are required to use epoxy molding compounds. Aluminum and Kirksite are used for the non-reinforced materials to mold coil coverings. Aluminum molds are used to make radio cases from a cold loaded glass reinforced compound. Well over 1,000 parts have been made without any indication of mold wash. Epoxy parts are made using a glass filled compound in a cast epoxy mold. These parts were made using a compression system.

There are precautions that must be observed in using epoxy molding compounds with regard to mold release agents and other molding materials. The silicone release agents are not required and should not be used, as they do have a deleterious effect on the handling and possibly on the end properties of the finished part. Silicone, polyethylene, and other such release assisting materials may cause sticking. They appear to counteract or possibly "over wet" the metal, get into the pores, and "root" there. Mold release agents also tend to inhibit the cure of the part. In one instance after a long period of time at 400°F., a film on a metal insert was traced directly to the mold release agents.

If the mold has been used for alkyd, polyester, or diallylphthalate, it is suggested that several "shots" of phenolic, urea, or melamine be used to purge the surface. Then apply a light coat of carnauba wax on the mold. Continuous waxing is not required and should not be done.

The time required for cure is contingent on the weight of material, configuration, and preheat. Small parts such as ½ watt resistor may require 45 seconds, a 35# part may require as long as 23 minutes.

In using epoxy molding compounds, parts can be produced on a production basis, probably not at the rate that would be obtained using phenolic, urea, or alkyd, because epoxy molding compounds do require a little longer cure.

—■—

edited by
L. Paggi,
E. I. duPont de Nemours & Co., Inc.

SPE ANTEC

You'll get a better product tomorrow

Every phenolic compound we formulate is proved in our Development Laboratories. It is molded on our most advanced equipment to determine how you can achieve optimum performance. Typical tests conducted are those for physical properties, chemical and electrical characteristics, molding and curing behavior.

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BMM 7001 was developed for use in cold powder automatic molding where mold and flash release are important. It is practically free of dust and fines. *BMM 7002* is ideal for plunger molding when you want fast plunger travel and cure. Both materials are available in black and brown.

Bringing you the newest and best in molding materials is our business. That's why our 49 years of experience are backed by the most modern and complete technical facilities available. Find out how valuable this policy can be to you. Talk to your Union Carbide Plastics Company representative. Or write Dept. AS-03G, Union Carbide Plastics Company, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. *In Canada:* Union Carbide Canada Limited, Toronto 7.

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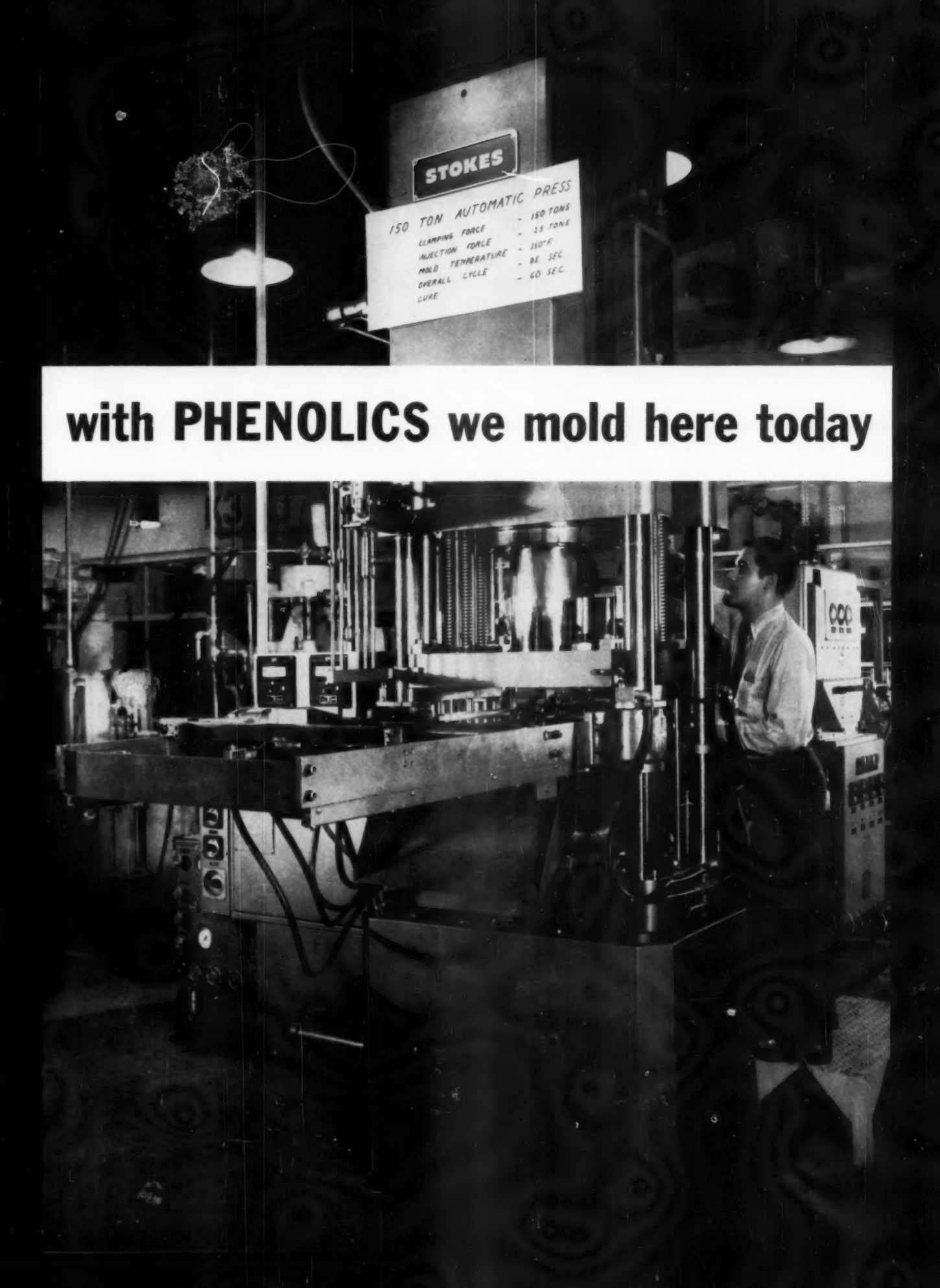
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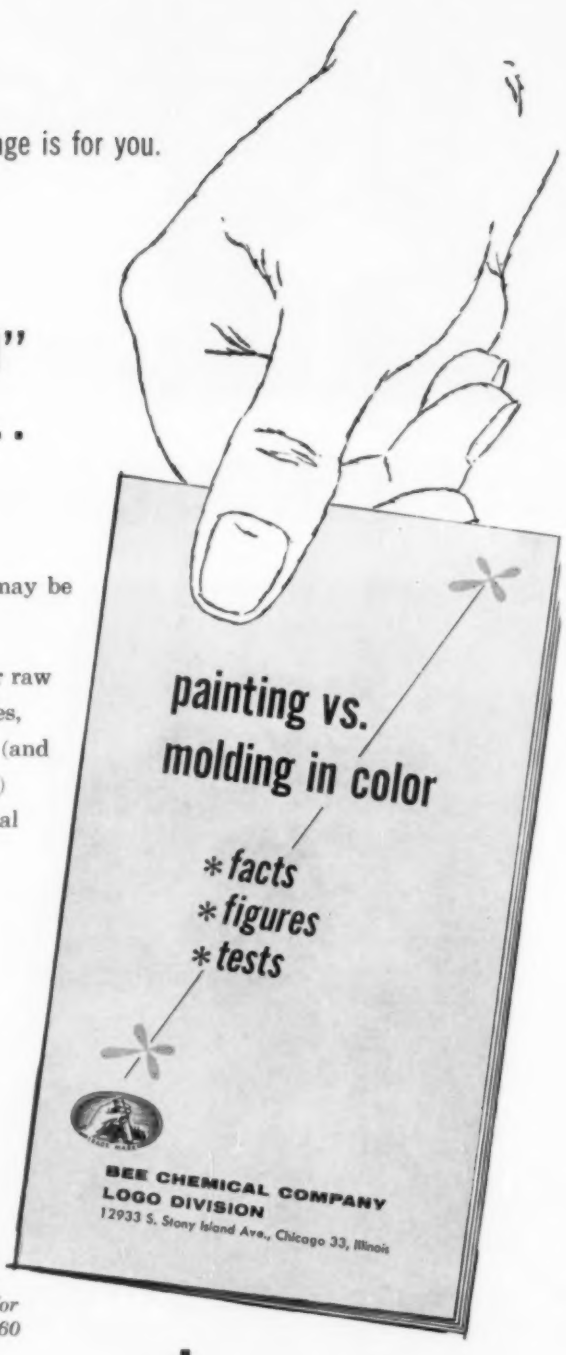

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SPEAKING OF EXTRUSION

Applications of Large Nylon 6 Extrusion Castings

The areas in which extrusion is playing an important part in producing finished items is increasing. One process fast becoming of importance is extrusion-casting. Several of the many applications of a recently developed process for manufacturing large items by extrusion-casting are discussed in this article.

Ordinary extrusion equipment (1¼" to 1¾" extruders are preferred) will operate satisfactorily, and simple, low cost molds may be used. General purpose Nylon 6 can be used for most applications, but in some cases a higher viscosity resin is preferred.

The only limit on the shape and design of articles is the limitation as to size of the molds. Parts are about 95% finished when they are removed from the molds and normally only minor finishing is required. It is possible to mold in undercuts as well as to incorporate inserts (*Figure 1*).

The surface texture can be varied by altering processing conditions or mold surface. All the factors which result in voids, drops, pits, sink marks, etc; can be easily controlled so that such defects are eliminated in the molding operation.

The size of parts, again, is only limited by the molds that can be constructed. Items as large as 6 feet in diameter have been produced. There is also no limit on thickness since any depth of casting can be produced within the same tolerance limits and property specifications.

One major advantage of this process, unlike many others, is that standard equipment and low cost molds may be used. Short, economical runs, therefore, are definitely possible.

Several applications discussed in this article include propellers, industrial truck wheels, "Warbler" couplings, gears, sections of outboard motors, and many others.

Nylon 6 Propellers

The limiting factor which affects the diameter of the molding is the mold itself. That is, how large can a mold be made before it becomes economically advisable to manufacture separate blades and assemble them on a metal hub? To date, propellers up to 36 in. have been made in a single mold, including both three- and four bladed units. In sizes greater than 36 in. the blades themselves have been molded and assembled on a metal hub (*Figure 2*).

Major advantages of the resultant product are:

1. Less weight since nylon 6 has a specific gravity less than most metals used for propellers.
2. Less fly wheel action when the propeller is reversed.
3. Greater resistance to erosion due to cavitation effects than materials normally used.
4. Greater shock and impact resistance especially when operating in ice infested waters. This is due to the greater flexibility of nylon 6 propellers.
5. Minimum finishing is required. Usually only the sprue must be removed before the unit is ready for use.
6. Very favorable cost. The finished propellers are very competitive with standard products.

An example of nylon 6 used as a propeller will help to illustrate its advantages. A Danish mail boat sailing between Denmark and Greenland normally required three to four propeller changes each year due to damage caused by ice. After being fitted with a nylon propeller, (1) the operators reported that it is still in excellent condition after two years of use.

Other advantages of using the extrusion-casting system are, (1) that

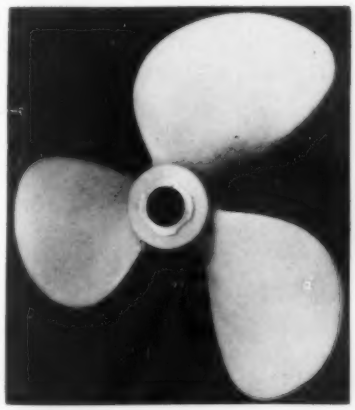

Figure 1. Twenty inch, one piece, three bladed nylon propeller with metal insert molded in.

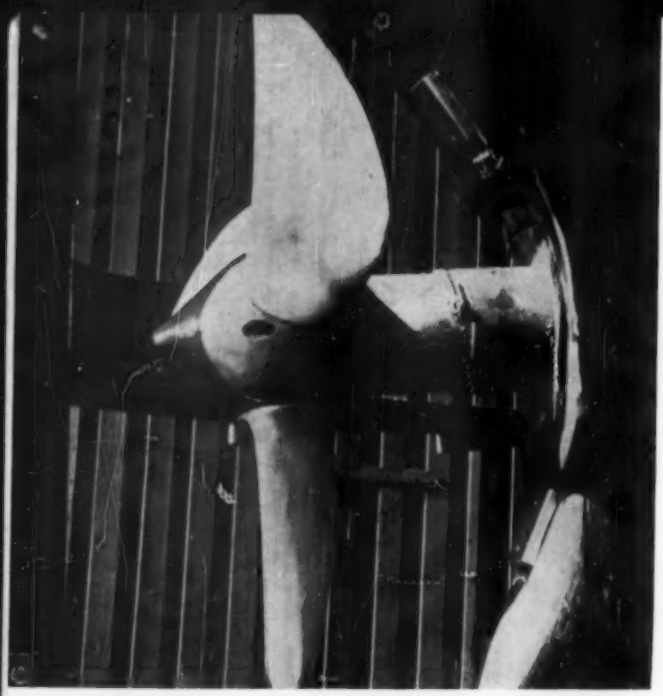

Figure 2. Nylon propeller blades assembled on metal hub and installed on fishing trawler.

a smaller number of molds are required to cover the complete range of pitch sizes needed, and (2) mounting the blades on a hub makes it possible to correct propeller pitch to conform closer to the maximum operating characteristics of the hull and power plant.

Hinge Stones (Warbler Couplings)

The hinge stone or "Warbler Coupling" in the steel industry is used as a shock and bearing support between interconnected rolling mills. The coupling absorbs the sudden shock when the roll mills begin to process the steel, thus preventing the shock from being transmitted to the main drive unit. Each of the parts weigh about five and a half pounds, and the application is now consuming approximately 10,000 pounds of nylon 6 each month.

These couplings remain self-lubricating after having been coated with molybdenum disulfide. Their life has been increased ten fold over that of previous couplings and the power requirements have been reduced.

Figure 3. Spur drive gear.

Industrial Truck Wheels

Nylon 6 wheels have proved to be far superior to those fabricated from solid rubber or phenolic. Trucks equipped with nylon 6 wheels and with standard wheels have been compared under actual working conditions. Some of the advantages of trucks with nylon 6 wheels are:

1. Maintenance was substantially reduced.
2. Power consumption was decreased by as much as 30%, thereby reducing battery care.
3. Operational speed of trucks would be increased 3-4½ mph.
4. Trucks could be used on floors where they had been prohibited because of the possibility of floor damage.

One particular case study involved a truck type which had a history for poor wheel wear. When fitted with nylon 6 wheels, no further wheel trouble occurred. In spite of its having quite a big wheel and nylon being somewhat more expensive the decision was made to use the nylon wheels as standard equipment. The Engineering Director stated that if a maintenance man had to be sent out to change a rubber wheel it would be much cheaper to use nylon to begin with. After careful evaluation of the test truck for 6 months, the wheels were found to be 0.016 in. (.45 mm) smaller in diameter than when initially installed. Calculations showed that even this rate of wear means a life of 10 years or much longer than the manufacturer wants the trucks to last. The same wheel measured after months was found to have the same rate of wear (wheel diameter was reduced 0.02"-0.5 mm). There was no change in this rate after the seventh month.

Large Gears

Gears with diameters up to 36 in. and 4 in. faces have been extrusion cast from nylon 6. Some of the advantages of these gears are:

1. Measured wear resistance.
2. Greater shock absorbency.
3. Self-lubricating.
4. Self-aligning.
5. Require minimum of finishing after removal from the mold.
6. Standard hobbs can be used for cutting teeth.

Cast Outboard Motor Sections

The entire bottom half of an outboard motor including the differential housing, cavitation plate, and keel plate have been cast at one time. The drive shaft tube and the gear housing were molded in as inserts.

Advantages of such a method are:

1. Low weight.
2. Anti-corrosion.
3. Ease of fabrication since only a minimum of finishing is required.
4. Greater flexibility and impact resistance over die cast parts.

Large Cast Slabs and Rounds

It is possible to cast nylon 6 slugs to nearly the dimensions of parts to be machined from them thus reducing the cost and time needed to produce finished items. The slabs and rounds can be made very uniform in density and without strains. The molds are relatively cheap since ¼" plate can be used. There are no voids, cavities or sink marks in the casting. The major advantage of being able to produce short runs is an important big factor.

In conclusion it may be said that extrusion-casting opens wide horizons for the production of large molded pieces that could not be produced economically, especially in short runs, on conventional injection molding and extrusion equipment.

Propellers of the type mentioned in the article are being manufactured for evaluation purposes at the present time by Columbia Bronze Company, Freeport, L.I., New York.

edited by **Bruce H. Maddock,** *Union Carbide Plastics Co.*

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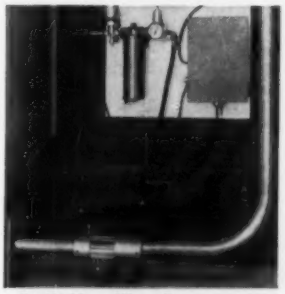

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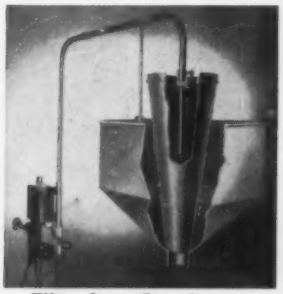

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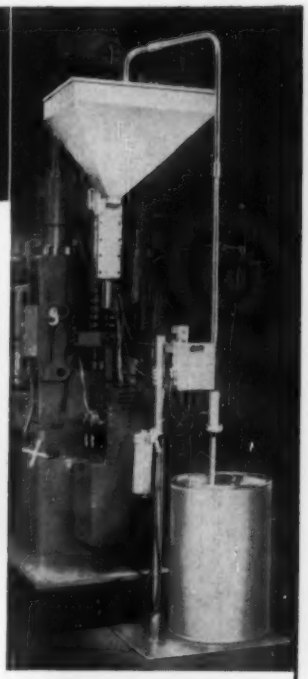

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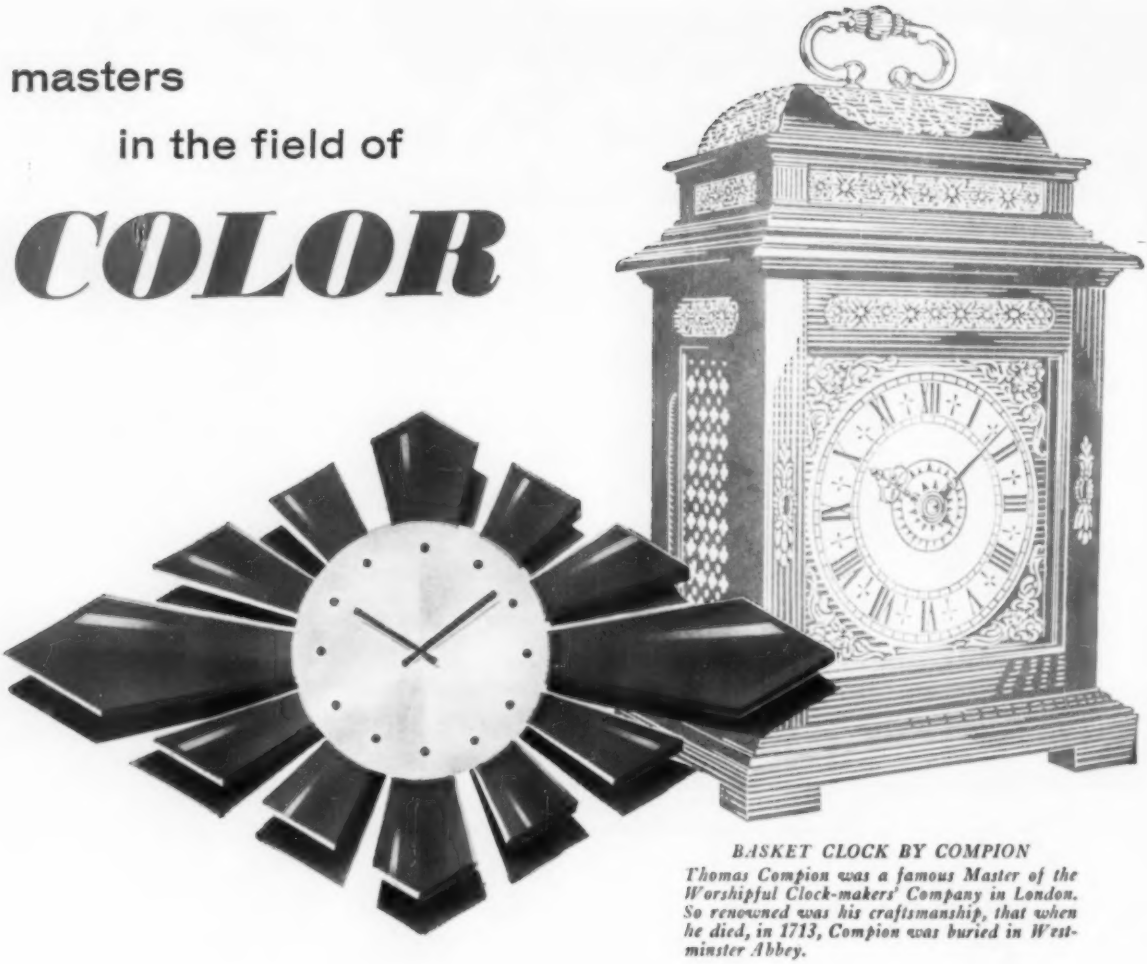

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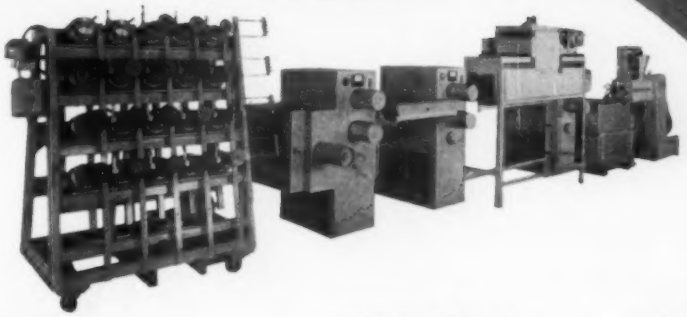

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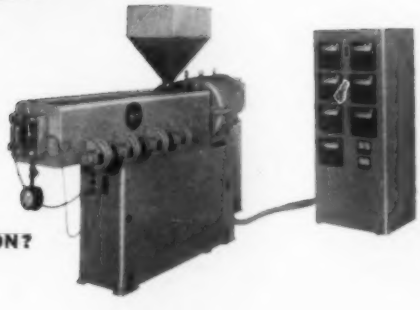

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REINFORCED PLASTICS

How Storage Conditions of Glass Fabric Affects . . .

Strength of Reinforced Laminates

Strength properties of laminates made from fabric exposed to 30 and 65% relative humidities for 1 week and 1 month were found to be unaffected. When humidity was upped to 97%, strength was significantly reduced.

The Forest Products Laboratory in the past few years has had difficulty obtaining glass fabric capable of making laminates that would meet the minimum requirements of a certain government specification. Suspicion was cast on the effect of shipping and storage conditions, to which the fabric was exposed before being laminated, on the eventual strength properties of the finished laminate. Consequently, the Materials Laboratory, Wright Air Development Center, requested the Forest Products Laboratory to consider the problem and initiate a test program covering some of the conditions that can be simulated and evaluated. "The material here presented is based on WADC Technical Report 58-441."

Effect of Humidity

The fabric, before being laminated into panels, was stored at 30, 65, and 97 percent relative humidity (RH). Analysis of test results of four groups of laminates tested indicated that the effects of storing fabric at the 2 lowest humidities were about the same—no significant change in properties.

Storage of fabric at 97 percent relative humidity, however, resulted in an apparent weakening of certain strength properties of some laminates. Storage at this humidity for one week did not, in general, result in more than a moderate reduction in dry strength properties, but appeared to have a greater effect on the wet strength properties. Storage of the fabric for 30 days generally had an additional deleterious effect on the strength of laminates.

In view of some moderate differences in strength between laminates and the differences between standard deviations for the average values, the properties of laminates made with fabric exposed to 97 percent relative humidity were tested statistically with those of laminates made from fabric exposed to the 2 lower humidities. Most of the differences in properties were statistically significant at the 5 percent level. From these observations and the statistical analysis, it was considered reasonable to make a general comparison of the strength properties of laminates fabricated after high humidity conditioning of fabric to the laminate made of fabric subjected to the least severe humidity conditions.

In the following discussion on the effects of humidity, the laminate of each group that was made of fabric exposed to about 30 percent relative humidity for 1 week will be referred to as the control laminate, and its strength

The Test Materials and Conditions

Fabric—181 glass fabric with three types of finishes was used—Volan A, 136, and Garan.

Resins—Polyester—Paraplex P-43 and Epoxy—Epon 828 with curing agent CL.

Exposure Conditions—Fabric was conditioned for 1 week or 1 month at 80°F. and (a) 30% RH, (b) 65% RH, and (c) 97% RH.

Fabrication Conditions—Polyester laminate was fabricated (a) in conditions at which fabric was exposed or (b) at standard conditions after fabric had been heated for 1 hour at 250°F and cooled. Epoxy laminate done at (a) standard conditions immediately after heating fabric at 200°F. for ½ hour or (b) after fabric was heated at 250°F for 1 hour.

Specimen Conditioning—All specimens tested were conditioned in a normal atmosphere maintained at 73°F. and 50% relative humidity for at least 1 month before testing.

Specimen Testing—Tests were made after normal dry conditioning or after two hours immersion in boiling distilled water with maximum load only being recorded. Tension tests were made with dry specimens only, but compression and bending tests were made with both dry and wet specimens, the even-numbered specimens being used in the wet test.

The first tensile specimens tested from the panels made with 181 136-finished glass fabric and Paraplex P-43 resin were inadvertently tested at a head speed of 0.02 inches per minute; the remainder of these panels were then tested at this speed. The panels with the other fabrics were tested at 0.2 inch per minute in tension.

The compression specimens were tested using the supporting apparatus described in Method 1021.1 of Federal Specification L-P-406b, at a head speed of 0.05 inch per minute.

The flexural specimens were tested flatwise with center loading over a 2-inch span, at a head speed of 0.05 inch per minute.

SPE ANTEC

properties as the control strength. Laminates made of fabric exposed to 65 percent relative humidity are considered laminates exposed to moderate humidity. Similarly, those laminates made of fabric exposed to 97 percent relative humidity are considered laminates exposed to high humidity. Some comparisons will be made between the strength properties of control laminates made of fabric exposed to 30 percent relative humidity and those made of fabric exposed to the high humidity of 97 percent relative humidity. This is, in general, the severest comparison to be made, but for fabric exposed at a relative humidity of less than 97 percent, the difference in strength properties of laminates was usually not appreciable.

Exposure of 136-finished fabric to the high humidity of 97 percent resulted in laminates the strength properties of which were consistently lower than those of the control laminate (table I). These differences in strength were from 2 to 8 percent in tension, 7 to 14 percent in dry compression, 6 to 9 percent in wet compression, 2 to 10 percent in dry flexure, and 5 to 14 percent in wet flexure.

Properties of laminates made with Garan-finished fabric that was exposed to 97 percent relative humidity were sometimes higher, but usually lower, than the corresponding strength of the control laminate (table II). These differences in strength were from 6 percent higher to 8 percent lower in tension, 7 to 21 percent lower in dry compression, 0 to 14 percent lower in wet compression, 5 percent higher to 1 percent lower in dry flexure, and 5 to 9 percent lower in wet flexure.

The polyester laminates made with Volan A-finished fabric showed greater effects of humidity than either of the other polyester laminates (table III). The strength of the laminates made of fabrics exposed to high humidity, as compared with that of the control laminate, which was exposed to 30 percent relative humidity for 1 week, were from 2 percent higher to 15 percent lower in tension, 1 percent higher to 11 percent lower in dry compression, 19 to 43 percent lower in wet compression, 6 to 18 percent lower in dry flexure, and 14 to 36 percent lower in wet flexure. The effect of humidity on strength was substantial, particularly for laminates that were tested after wet conditioning.

Effects of humidity on epoxy laminates reinforced with Volan A-finished glass fabric were not nearly so severe as those on the polyester laminates reinforced with Volan A-finished fabric (table IV). The strength properties of the laminates made of fabric exposed to 97 percent relative humidity were from 4 percent higher to 7 percent lower in tension, 1 to 8 percent higher in dry compression, 8 percent higher to 17 percent lower in wet compression, 5 percent higher to 5 percent lower in dry flexure, and 3 to 22 percent lower in wet flexure than the corresponding controls.

Table I. Results of Tests of Laminates Made with 181 136-Finished Glass Fabric and Paraplex P-43 Resin. Fabric Exposed in Three Different Relative Humidities Before Laminates Were Made.

Panel No.	Duration of exposure	Layup[1] condition		Tensile strength Dry[2]	Compressive strength Dry	Compressive strength Wet[3]	Modulus of rupture Dry	Modulus of rupture Wet	Increase in weight after 2-hour boil[4]
	Days			P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	Percent
Exposure at About 30 Percent Relative Humidity									
596	7	A	Av.	[5]51,800	47,100	40,700	67,300	61,800	0.24
			S	[6]1,130	1,310	1,240	2,330	690	
602	30	A	Av.	48,200	46,600	37,800	64,200	59,700	.26
			S	820	2,630	590	1,930	920	
599	7	B	Av.	50,100	45,600	39,600	67,300	59,800	.31
			S	1,170	2,340	1,900	1,490	1,280	
605	30	B	Av.	49,600	46,900	39,000	64,600	58,000	.28
			S	1,280	1,230	920	680	1,810	
Exposure at 65 Percent Relative Humidity									
597	7	A	Av.	49,800	47,700	38,300	66,800	60,700	.32
			S	1,100	1,620	2,190	970	1,350	
603	30	A	Av.	49,300	46,700	40,700	65,800	61,300	.24
			S	2,090	2,980	1,180	2,890	2,330	
600	7	B	Av.	49,000	46,500	41,100	63,700	61,000	.24
			S	930	2,310	1,120	1,770	1,160	
606	30	B	Av.	52,000	[7]47,100	41,300	66,300	59,500	.29
			S	990	1,260	380	1,320	1,720	
Exposure at 97 Percent Relative Humidity									
598	7	A	Av.	50,900	42,800	37,200	65,700	58,700	.31
			S	1,460	1,370	2,260	1,630	1,010	
604	30	A	Av.	49,300	40,500	36,900	60,700	55,500	.40
			S	1,370	2,370	3,330	1,050	510	
601	7	B	Av.	49,900	42,700	38,100	62,600	58,300	.25
			S	650	1,900	1,070	1,940	1,510	
607	30	B	Av.	[7]47,600	43,800	38,100	60,900	53,300	.32
			S	790	1,760	1,210	1,210	1,050	

[1] Condition A denotes layup of fabric and resin made in atmosphere in which fabric was exposed. Condition B denotes fabric ovendried 1 hour at 250°F. before layup.

[2] Dry specimens tested after conditioning at 73°F. and 50 percent relative humidity.

[3] Wet specimens tested after 2 hours' immersion in boiling distilled water.

[4] Based on change in weight of flexural specimens.

[5] Average of five specimens.

[6] S denotes within plot standard deviation based on range of plot.

[7] Average of four specimens.

Considering all three humidity conditions, the analysis of variance showed that differences in the compressive and flexural strength properties for all laminates and for tensile strength properties of the laminates made with Volan A-finished fabric were statistically significant at the 1 percent level. The differences in tensile strength of the polyester laminates reinforced with Garan-finished fabrics were significant at the 5 percent level; however, the analysis of this group using the least significant difference indicated there was no statistical difference between fabrics exposed to the 3 different humidities. The differences in tensile strength for the polyester laminates reinforced with 136-finished fabric were not statistically significant, which appears reasonable in view of the moderate changes in strength.

Effect of Length of Exposure of Fabric

The fabric was stored at 3 different conditions of relative humidity for 7 or 30 days before being laminated into panels. The increased period of exposure at 30 and 65 percent relative humidity did not usually result in laminates having appreciably lower strength properties. There are some indications, however, of strength loss with increased time of exposure of fabric at both of these humidities. It may be that prolonged exposure, such as for 6 months or 1 year, would result in further decreases in strength.

Length of exposure of fabric at 97 percent relative humidity had a pronounced effect on certain strength properties of some laminates. The greatest reduction in strength occurred in the Volan A-finished laminates, in both the polyester and epoxy groups.

For the 136-finished laminates, the length of exposure of the fabric at any humidity resulted in less than 10 percent difference in any of the strength properties when comparing comparable values for 7 and 30 days' exposure. These differences were also less than 10 percent for the Garan-finished laminates, except for dry compressive strength of laminates made from fabric conditioned at 97 percent relative humidity. In this instance, where fabric was not oven-dried before laminating, the average compressive strength values were 42,300 and 36,800 pounds per square inch after 7 and 30 days' fabric exposure, respectively. This difference may not be of practical significance in view of the rather large standard deviations associated with each average value.

Only 1 of the strength values of the polyester and epoxy laminates

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Table II. Results of Tests of Laminates Made with 181 Garan Finished Glass Fabric and Paraplex P-43 Resin. Fabric Exposed in Three Different Relative Humidities Before Laminates Were Made.

Panel No.	Duration of exposure	Layup[1] condition		Tensile strength Dry[2]	Compressive strength Dry	Compressive strength Wet[3]	Modulus of rupture Dry	Modulus of rupture Wet	Increase in weight after 2-hour boil[4]
	Days			P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	Percent
Exposure at About 30 Percent Relative Humidity									
620	7	A	Av.[5]	43,100	46,800	39,600	52,700	58,200	0.22
			S[6]	1,440	3,320	2,960	1,600	1,070	
626	30	A	Av.	39,400	46,300	44,100	51,600	56,200	.20
			S	1,860	2,100	720	1,020	1,150	
623	7	B	Av.	44,100	43,900	40,700	53,400	56,000	.28
			S	1,190	2,320	3,500	1,020	1,390	
629	30	B	Av.	43,200	44,400	41,000	51,500	56,500	.26
			S	1,720	1,940	4,820	1,720	958	
Exposure at 65 Percent Relative Humidity									
621	7	A	Av.	43,900	44,500	41,500	52,800	56,400	.21
			S	1,360	4,360	1,660	1,230	2,100	
627	30	A	Av.	43,300	45,600	43,100	53,400	57,500	.21
			S	1,490	1,340	1,890	1,650	1,210	
624	7	B	Av.	42,100	44,600	40,800	54,100	57,300	.17
			S	940	1,205	1,670	1,280	1,560	
630	30	B	Av.	43,900	41,700	41,400	54,200	55,800	.15
			S	480	3,480	1,230	1,280	1,350	
Exposure at 97 Percent Relative Humidity									
622	7	A	Av.	45,800	42,300	37,100	55,300	54,900	.28
			S	2,070	3,000	5,270	1,130	1,258	
628	30	A	Av.	43,200	36,800	34,200	54,000	52,700	.33
			S	1,620	1,950	350	570	990	
625	7	B	Av.	40,500	43,400	39,700	52,400	54,600	.18
			S	2,590	1,340	980	880	1,000	
631	30	B	Av.	39,500	40,700	37,400	52,900	55,300	.20
			S	1,370	2,010	1,350	990	1,600	

[1] Condition A denotes layup of fabric and resin made in atmosphere in which fabric was exposed. Condition B denotes fabric ovendried 1 hour at 250°F. before layup.
[2] Dry specimens tested after conditioning at 73°F. and 50 percent relative humidity.
[3] Wet specimens tested after 2 hours' immersion in boiling distilled water.
[4] Based on change in weight of flexural specimens.
[5] Average of five specimens.
[6] S denotes within plot standard deviation based on range of plot.

made of Volan-finished fabric exposed at 30 and 65 percent relative humidity had a decrease in strength of more than 10 percent from 7 to 30 days' exposure of fabric. This value occurred in the polyester laminate made from fabric exposed at 65 percent relative humidity and ovendried before laminating, where the wet compressive strength values of the laminates were 31,200 and 27,700 pounds per square inch. Decreases in strength of up to 30 percent for the polyester laminates and up to 23 percent for the epoxy laminates, however, were noted with increased time of fabric exposure at 97 percent relative humidity.

From the overall statistical analysis, length of exposure had a statistical significance on the tensile and flexural strength of all laminates, and on the compressive strength of the Volan A polyester laminate. Differences in the compressive strength of the polyester laminates made with 136-finished and Garan-finished fabrics and of the epoxy laminate made with Volan A-finished fabric were not statistically significant. From a practical viewpoint, however, analysis of the data indicates that the compressive strength of both the Garan-finished polyester laminates and the epoxy laminates were substantially reduced when fabric had been exposed at 97 percent relative humidity.

Effect of Ovendrying Fabric at 250°F. Before Laminating

After exposure of fabric at the 3 humidity conditions for 7 or 30 days, one-half of the fabric was laminated by the usual procedure and the other half was dried in an oven for 1 hour at 250°F. This ovendrying cycle has been recommended by some fabricators as a method of eliminating, or at least minimizing, effects of moisture picked up by the fabric during usual storage conditions.

Ovendrying the fabric after exposure resulted in rather moderate, inconsistent results (tables I through IV). Sometimes the drying appeared to be somewhat beneficial, at other times it seemed to have no effects, and then at still other times the effect seemed to be detrimental. Analysis of data from laminates made with fabric exposed at 30 and 65 percent relative humidity indicates that there is no definite trend to establish any consistent benefit or degradation due to ovendrying. This is true of all strength properties of each of the four groups of laminates.

After exposure of fabric at 97 percent relative humidity, the practical significance of the ovendrying effects are also clouded by the apparent increase, lack of change, or decrease in strength due to drying. From an overall statistical analysis, differences in tensile and compressive strength of the laminate made with 136-finished fabric and differences in compressive and flexural strength of the laminate made with Garan-finished fabric are not significant at the 5 percent level.

Table III. Results of Tests of Laminates Made with 181 Volan A-Finished Glass Fabric and Paraplex P-43 Resin. Fabric Exposed in Three Different Relative Humidities Before Laminates Were Made

Panel No.	Duration of exposure	Layup[1] condition		Tensile strength Dry[2]	Compressive strength Dry	Compressive strength Wet[3]	Modulus of rupture Dry	Modulus of rupture Wet	Increase in weight after 2-hour boil[4]
	Days			P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	Percent
Exposure at About 30 Percent Relative Humidity									
608	7	A	Av.	[5]58,800	43,700	31,300	68,300	54,600	0.35
			S	[6]850	3,160	1,450	1,750	1,140	
614	30	A	Av.	58,400	46,000	28,400	65,900	52,400	.39
			S	1,130	910	1,060	1,380	650	
611	7	B	Av.	57,400	43,600	26,900	65,200	51,200	.38
			S	1,850	2,000	2,640	1,700	960	
617	30	B	Av.	57,600	42,000	26,200	65,400	47,100	.33
			S	890	1,170	420	1,610	800	
Exposure at 65 Percent Relative Humidity									
609	7	A	Av.	58,700	47,500	31,500	66,800	49,600	.47
			S	2,050	630	420	980	730	
615	30	A	Av.	57,600	49,300	31,100	66,900	52,100	.37
			S	1,410	630	560	1,970	1,060	
612	7	B	Av.	58,000	44,100	31,200	65,800	52,000	.34
			S	630	2,710	960	1,520	790	
618	30	B	Av.	56,500	45,500	27,700	66,300	50,800	.33
			S	920	1,250	1,000	1,550	740	
Exposure at 97 Percent Relative Humidity									
610	7	A	Av.	59,700	43,300	25,300	64,000	43,500	.51
			S	1,260	1,020	1,680	1,350	1,060	
616	30	A	Av.	49,800	38,900	17,700	55,900	34,800	.67
			S	1,190	2,120	940	680	640	
613	7	B	Av.	55,600	44,000	24,700	61,000	46,800	.43
			S	1,040	1,590	1,170	670	470	
619	30	B	Av.	53,100	42,800	20,700	60,300	42,000	.43
			S	2,000	1,490	1,830	1,570	1,280	

[1] Condition A denotes layup of fabric and resin made in atmosphere in which fabric was exposed. Condition B denotes fabric ovendried 1 hour at 250°F. before layup.
[2] Dry specimens tested after conditioning at 73°F. and 50 percent relative humidity.
[3] Wet specimens tested after 2 hours' immersion in boiling distilled water.
[4] Based on change in weight of flexural specimens.
[5] Average of five specimens.
[6] S denotes within plot standard deviation based on range of plot.

Although differences in the overall flexural strength of the laminate made with Garan-finished fabric are statistically significant, the data did not indicate any definite practical significance, since some of the data denote improvement and others degradation due to the ovendrying. After 30 days' exposure of Volan A-finished fabric at 97 percent relative humidity, there generally appeared to have been a slight improvement gained by ovendrying of the fabric before laminating. This is true in tension, compression, and flexure for the polyester laminate and in compression and flexure for the epoxy laminate. The data are inconsistent with the effects noted after 7 days' exposure at the same humidity; hence it is doubtful if they are of practical significance. From the overall statistical analysis of the Volan A-finished laminates, the ovendrying effects were not significant in flexure for the polyester laminate nor in tension or compression for the epoxy laminate.

Effect of Testing Laminates Dry or Wet

While the other three main variables pertain to conditions affecting the fabric, tests of laminates after normal conditioning or after 2 hours' immersion in boiling water indicate the differences between dry and wet strength properties. These dry and wet tests were made in compression and flexure only. It is generally conceded that tests after 30 days' immersion in water at room temperature are more realistic of wet service conditions than are tests after 2 hours' immersion in boiling water. Considerable data have been accumulated, however, to show that the strength properties after exposure to both of these conditions are reasonably similar. Hence, wet strength properties reported and evaluated herein are believed to be reasonable representations of the expected wet strength.

In most polyester and epoxy laminates, wet strength properties are usually less than the dry strength properties. This is reflected in various military specifications, which have somewhat lower strength requirements when the laminate is wet than when it is dry. The same trends were noted in all of the data on compressive strength obtained in this investigation, as well as in the data on flexural strength of all but the 181 Garan fabric laminates. The laminates made with Garan-finished fabric quite consistently showed an increase in strength after wet conditioning. In view of these results, data from the original check laminate of this roll of fabric were reviewed; this revealed that 2 hours' immersion in boiling water had also increased the flexural strength of the check laminate. Reasons for the increase in strength after 2 hours in boiling water are not known. Laminates reinforced with fabric having finishes other than Garan, however, also have been known to increase in strength after similar wet conditioning.

(*Continued on page 45*)

Table IV. Results of Tests of Laminates Made with 181 Volan A Glass Fabric and Epon 828-CL Resin. Fabric Exposed in Three Different Relative Humidities Before Laminates Were Made.

Panel No.	Duration of exposure	Layup[1] condition		Tensile strength Dry[2]	Compressive strength Dry	Compressive strength Wet[3]	Modulus of rupture Dry	Modulus of rupture Wet	Increase in weight after 2-hour boil[4]
	Days			P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	Percent
Exposure at About 30 Percent Relative Humidity									
632	7	A	Av.[5]	64,700	50,500	38,700	74,700	63,900	0.20
			S[6]	3,620	3,470	2,980	1,860	620	
638	30	A	Av.	67,600	52,500	42,800	80,200	64,700	.24
			S	540	1,530	2,030	1,610	1,170	
635	7	B	Av.	68,800	53,800	41,700	79,700	64,900	.30
			S	350	2,160	2,810	2,240	1,370	
641	30	B	Av.	67,700	54,800	41,100	80,700	63,800	.22
			S	2,220	3,730	3,120	1,950	260	
Exposure at 65 Percent Relative Humidity									
633	7	A	Av.	67,600	51,300	38,900	76,400	64,100	.25
			S	1,490	1,650	2,460	2,260	1,540	
639	30	A	Av.	67,200	49,600	41,100	77,500	62,400	.24
			S	1,240	1,240	1,570	2,780	870	
636	7	B	Av.	69,600	52,400	39,900	79,200	65,600	.20
			S	950	3,210	1,930	1,730	330	
642	30	B	Av.	69,800	51,400	37,300	78,500	62,200	.23
			S	1,080	4,800	2,580	1,250	920	
Exposure at 97 Percent Relative Humidity									
634	7	A	Av.	67,600	53,600	41,700	78,400	62,100	.37
			S	1,370	5,450	2,030	1,030	1,400	
640	30	A	Av.	60,700	50,900	32,000	70,600	49,800	.33
			S	860	3,220	3,080	1,460	4,460	
637	7	B	Av.	64,300	51,100	37,900	74,800	60,800	.29
			S	960	2,540	1,360	1,340	310	
643	30	B	Av.	59,900	54,300	34,200	72,900	53,200	.35
			S	2,510	3,420	1,860	1,400	1,220	

[1] Condition A denotes layup of fabric and resin made in standard atmosphere after ovendrying fabric for ½ hour at 200°F. Condition B denotes fabric ovendried 1 hour at 250°F. before laminating.
[2] Dry specimens tested after conditioning at 73°F. and 50 percent relative humidity.
[3] Wet specimens tested after 2 hours' immersion in boiling distilled water.
[4] Based on change in weight of flexural specimens.
[5] Average of five specimens.
[6] S denotes within plot standard deviation based on range of plot.

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Dimethyl Sebacate	0.986*	3.54 @30°C	Vinyl Resins, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate, Acrylic Resins	High Solvency and Efficiency, Wide Compatibility, Concentrated Source of Sebacyl Radical
Dioctyl Sebacate	0.913	17.4	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate	Excellent Low Temp. Flexibility, Low Volatility, Excellent Soapy Water Resistance, Good Electricals

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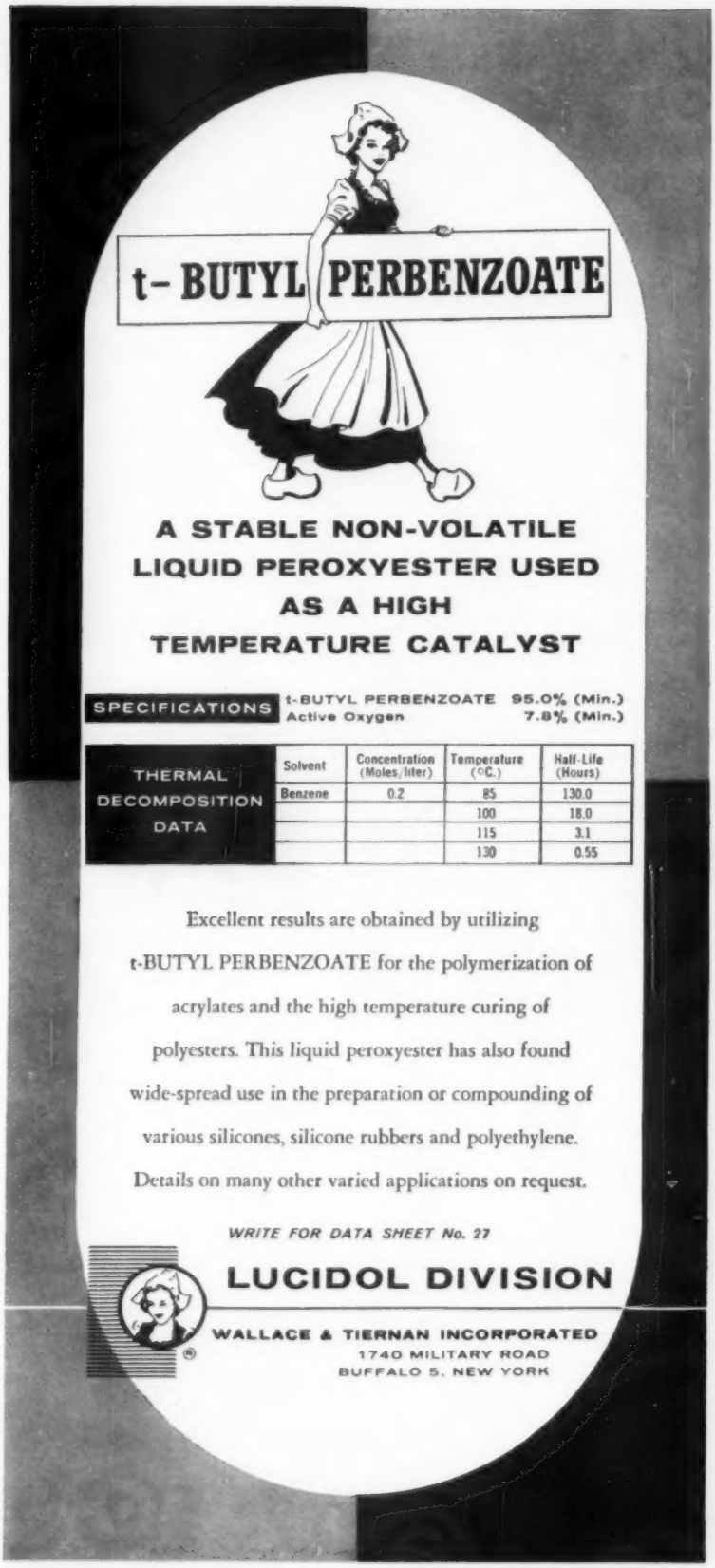
Except for the flexural strength of laminates made of Garan-finished fabric, each group of laminates showed a consistent decrease in compressive and flexural strength after wet conditioning. The smallest reduction in compressive strength occurred in the laminates made of Garan fabric. The greatest difference between dry and wet values occurred in the laminates made of Volan A-finished fabric with both the polyester and epoxy laminates consistently having substantial strength loss after wet conditioning. It appears that the loss in compressive and flexural strength was slightly more severe when fabric had been exposed to 97 percent relative humidity instead of to the lower humidity conditions.

From the overall statistical analysis, the differences between the dry and wet compressive strength properties and flexural strength properties are statistically significant at the 1 percent level. Except for the flexural strength of the laminates made with Garan-finished fabric, all strength values were decreased due to wet conditioning.

Conclusions

- Exposure of glass fabric to a high relative humidity before laminating had a deleterious effect on most of the strength properties of subsequent laminates. Exposing glass fabric to a low or moderate humidity before laminating had small, inconsistent effects on the strength properties of subsequent laminates.
- The effects of high humidity during storage of glass fabric on the strength properties of subsequent laminates are noted after as few as 7 days and are more pronounced after 30 days' storage.
- Ovendrying of fabric for 1 hour at 250°F. immediately before laminating had no consistent effect on the strength properties of subsequent laminates; in some instances the strength was improved and in others it was reduced.
- Strength properties of laminates made with Garan- and 136-finished glass fabric appeared to be affected less by fabric storage conditions before laminating than were those of laminates made with Volan A-finished fabric.
- The wet strength properties of laminates were generally affected more by the conditions of fabric exposure than were the dry strength properties.
- Compressive and flexural strength of laminates were affected more by conditions of fabric storage than was the tensile strength.

Edited by George Lubin
Grumman Aircraft Co.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PHYSICAL PROPERTIES	ASTM METHOD	UNITS	FORTIFLEX RESINS A-20	A-70	A-250	A-500
Melt Index	D-1238-52T	—	0.2	0.7	2.5	5.0
Heat Distortion Temp. (66 psi)	D-648-45T	°F.	185	185	180	180
Brittleness Temp.	D-764-52T	°F.	−200	−180	−160	−100
Impact Strength, izod (1/8" x 1/2" injection-molded bars)	D-256-54T	ft. lb./in. notch	23	18	13	3
Tensile Strength, Max., 0.2 in./min.	D-638-52T	psi.	3700	3600	3500	3300
Elongation, First Tensile Yield Point	D-638-52T	%	25	25	25	25

Properties of Fortiflex "A" Not Affected by Melt Index

PHYSICAL PROPERTIES	ASTM METHOD	UNITS	VALUE
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Refractive Index	D-542-50	n_D^{25}	1.54
Hardness, Shore D	D-676-49T		65
Stiffness	D-747-50	psi.	150,000
Water Absorption (1/8" specimen, 24 hr. immersion @ room temp.)	D-570-54T	%, wgt. gain	<0.01
Flammability	D-635-44	in./min.	1.0
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width		in./in.	0.02 to 0.04

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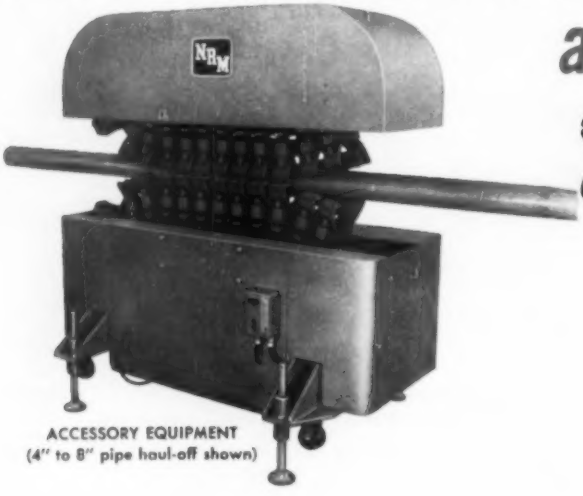

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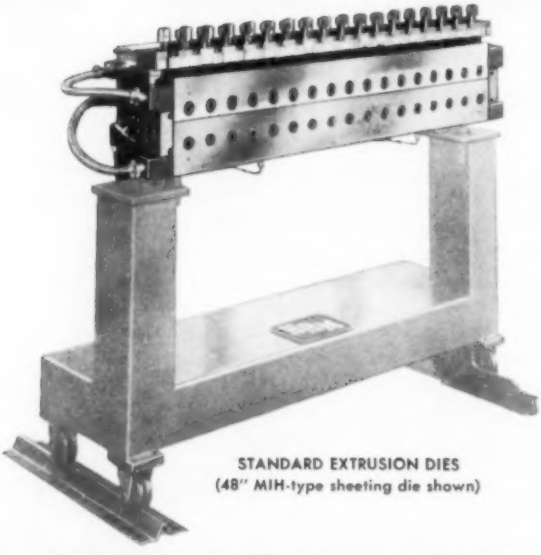

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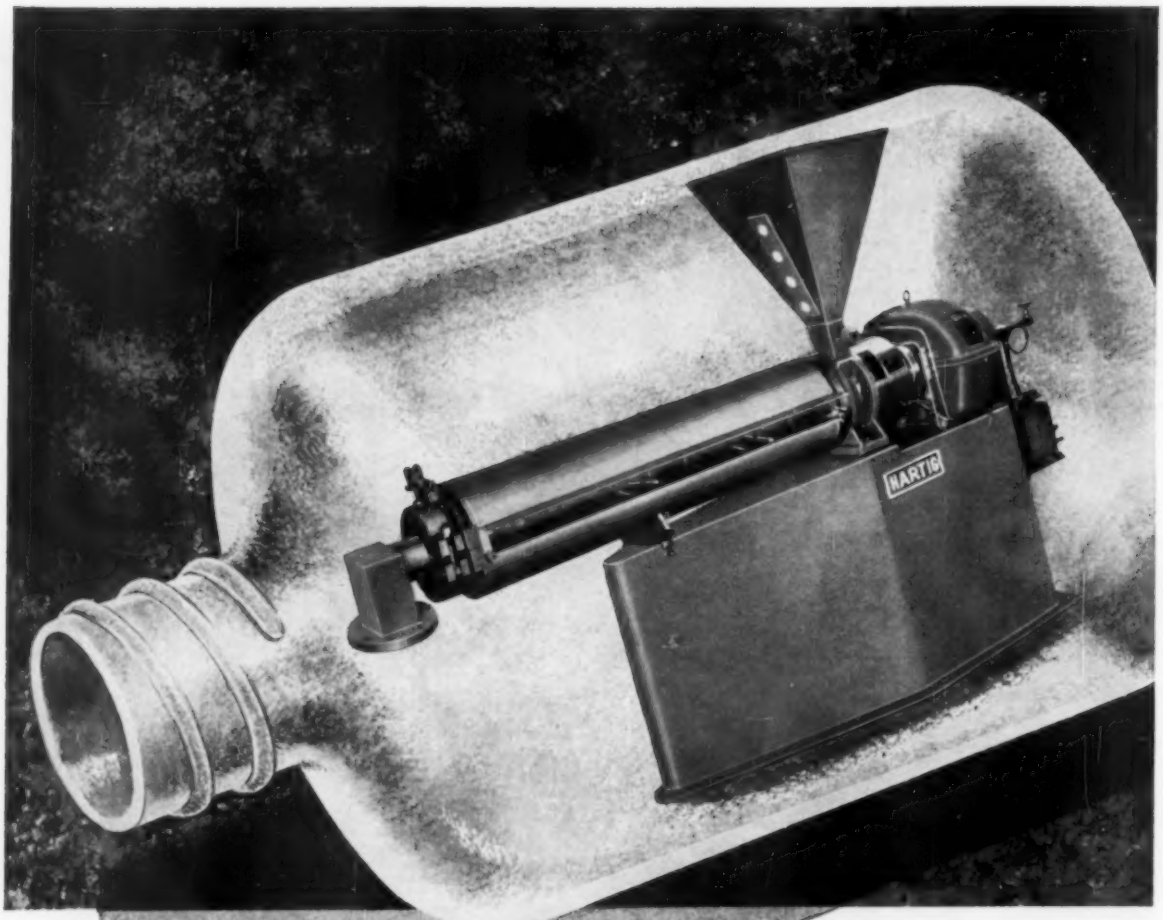

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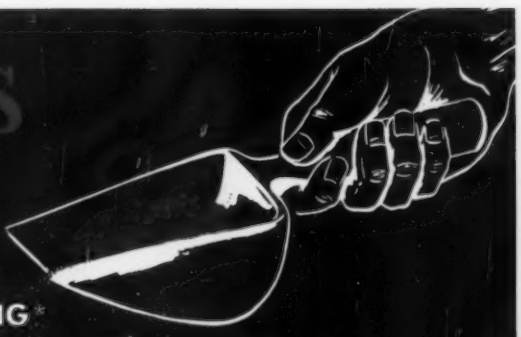

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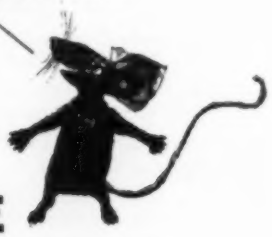

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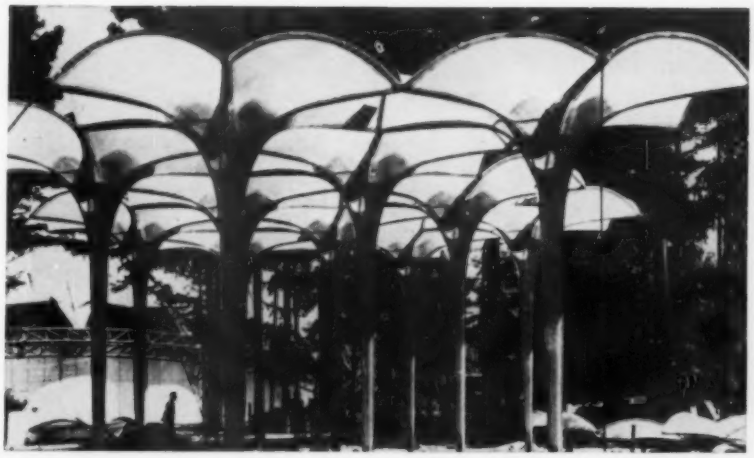

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POLYMER SCIENCE

Mechanism and Mechanics of Creep of Plastics

This is Part I of a 2 Part article—next month—Stress Relaxation and Combined Stress Creep of Plastics

Time dependent changes in the relation between stress and strain such as creep or stress relaxation are among the most important mechanical characteristics of plastics. The usefulness for structural applications or applications requiring dimensional stability is very severely limited for materials having significant time sensitivity at the temperature to be encountered.

Creep is usually considered to be a time dependent (or changing) strain (or deformation) in a material resulting from a constant stress (or load). Stress relaxation is a time dependent (or changing) stress resulting from a constant strain (or deformation). In the usual uni-axial tension creep test a constant load is applied to a specimen having a gage length of uniform cross-section. For small strains the stress is substantially constant during such a test. For large strains the stress increases with strain owing to the reduction in cross-sectional area. In the usual test the load is nevertheless kept constant. A few tests have been performed in which the stress was maintained constant by one of several devices.

At sufficiently high stress and temperature some materials, including some plastics, display a creep curve in which the creep rate is initially rapid, then (A) decreases for a period of time, (B) remains nearly constant for a period, and (C) increases rather abruptly. This increase in creep rate, when observed, is followed rather soon by fracture. The three regions denoted by A, B, C above are often referred to as primary creep, secondary (or steady-state) creep and tertiary creep, respectively.

Whether these divisions have any significance other than as arbitrary divisions of a curve is a debatable point. It seems to the writer that the secondary or so-called steady-state region may be no more than a transition between two(or more) mechanisms of deformation. Rarely are data found which show a true straight line over a substantial region of the creep curve. However, many of the analyses that have been made, until recently, of stress analysis problems for creep have been based on an assumption that the entire creep curve could be represented by a straight line, that is, a constant rate of creep. While this may have been an adequate way of treating design problems involving creep at low stresses over long periods of time, it is hardly adequate for many present-day problems which involve high stresses, high temperatures, and short times.

Mechanisms of Creep of Plastics

A discussion of the mechanisms of creep of plastics must still be somewhat generalized and speculative. For purposes of the present discussion three classes of plastics may be considered: (a) linear polymers, (b) space polymers, (c) reinforced plastics.

Linear Polymers

A linear polymer may be considered to be a chainlike addition of molecules, such as in polyethylene—a chain of carbon atoms with two much smaller hydrogen atoms attached to each carbon atom. In a solid these chains (macromolecules) may be related to each other in a completely random manner—looped, coiled and entangled one with another. The binding forces holding the elements of the chains together are strong primary atomic bonds, whereas in a solid the macromolecules are attached to one another by weaker molecular bonds (van der Waals' forces). Creep of such material involves rupture or interchange of these molecular bonds under the action of stress such that the molecules as a whole or segments of the molecules slide past one another. Probably not all bonds between one segment and

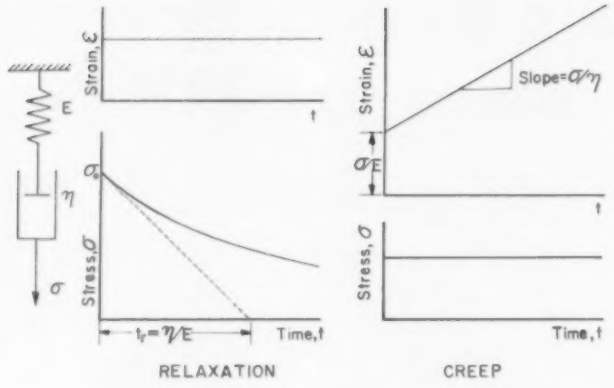


Figure 1. Relaxation and creep for the Maxwell unit

its neighbors are broken or interchanged at once but instead the ruptures or interchanges occur in sequence—one action initiating the next.

The actions involved may be a linear sliding of one molecule or molecular segment past another or a straightening, a twisting or an uncoiling depending on the molecule, its orientation and the nature of the stress applied. The ruptures or interchanges of bonds between neighboring atoms which permit the above actions are made possible by the fact that the individual atoms are in constant vibration about their mean positions due to thermal energy.

From quantum mechanical considerations it has been shown that the distribution of thermal energy in a solid at a uniform temperature is not uniform, nor does a given distribution among the atoms remain fixed. At any given time some atoms have significantly greater thermal energy than others and at a later time other atoms will possess the greater energy. This observation, together with the fact that many of the bond energies in high polymers are rather weak, especially in noncrystalline regions, so that the bond energy and thermal energy may be of the same order of magnitude, means that thermal oscillations have a considerable influence on mechanical behavior such as creep. Since there is among the atoms a spectrum of bond energies and a spectrum of thermal energies which nearly or actually overlap, relatively small stresses may produce strain energies sufficient to overcome the potential energy barrier for place change of certain atoms. Thus a continuous deformation may result as the thermal energy and bond energies are redistributed with time, the former in a random manner and the latter as a result of prior place changes.

The deformation of amorphous linear high polymers under stress is considered by Alfrey (1)† to consist of (a) an instantaneous elastic response, (b) a retarded elastic response, and (c) flow. The process involved in the last two is considered to be a diffusion process in which chain segments form the elements which may jump from one equilibrium position to another in the diffusion process. Under stress the diffusion is biased in the direction of the stress and chain segments diffuse into holes which are present in the structure or which open up as a result of prior diffusion. The results of a succession of segmental jumps will be an alteration in shape of the polymer molecule and a shift in the position of the center of mass. The wriggling about from shape to shape which is biased by stress is called micro-Brownian movement and is responsible for the retarded elastic response to stress. The wandering about of the center of mass which is biased by stress is called macro-Brownian movement and is a true flow.

If the chain length (or molecular weight) is small the sliding of one molecule past another occurs with some ease and the creep resistance is low. For longer chains a greater degree of entanglement occurs and such sliding is difficult—if not impossible, for some individual molecules without rupture of a chain. Also when molecules become very large the secondary bonds may become stronger especially for polar molecules. Since the primary bonds are usually much stronger than the secondary bonds, rupture of primary bonds is not likely to contribute significantly to the creep process for linear polymers.

A linear polymer may be made less flexible and more creep resistant by the presence of bulky atoms or side groups of atoms attached periodically along the chain as in polyvinyl chloride where a large chlorine atom replaces one of every four hydrogen atoms.

† Numbers in parentheses identify references at the end of this paper.

Crystallization in Polymers

A polymer crystallite is defined as a region having an internal structure which has a regular geometric pattern in space of structural elements extending over a considerable number of elements. The elements for polymers are like-sections of polymeric molecules. A crystalline polymer consists of a mixture of regions having different degrees of order from complete disorder (amorphous) to nearly perfect order (crystalline). A single molecule may extend through several crystallites (2).

Crystallization of polymers tends to increase strength and creep resistance, probably by permitting polymer chains to fit more closely to each other, resulting in increased density and greater strength of the secondary bonds holding the chains together. These greater bond forces together with mechanical interference resulting from the closer packing reduce the possibility of creep by slip in the crystalline regions. Whether slip may occur at all on crystallographic planes lying across polymer chains is not known to the writer. However, it seems unlikely to be a significant occurrence since strong primary bonds would be involved in such slip compared to the generally weaker secondary bonds involved in slip parallel to chain directions. The phenomenon of dislocations (3) in the crystal lattice as well as other defects such as inclusions of foreign particles or regions of entanglements of chains should affect the properties of polymer crystallites in a manner like that of similar defects in metal crystals. It is possible that slip in a polymer crystallite may take place at low stress by the mechanism of a moving dislocation. Whether a mechanism for continuous generation of dislocations such as the Frank-Reed source (3) operates in polymer crystallites is not clear.

Recent studies (4) of the mechanism of crystallization in linear polymers suggest the growth after nucleation of fibrillar crystallites growing in the direction of the polymer chains. These fibrils experience a coiling configuration and a haphazard branching with the branches growing along parallel paths, thus producing coiled families of fibrillar crystallites which may form larger structures of coiled fibrils radiating from a point, a line

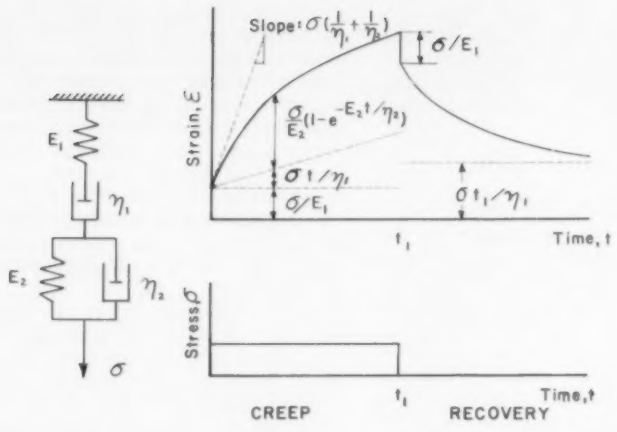


Figure 2. Creep and recovery for Maxwell and Kelvin units in series.

or a surface. It is evident that a detailed description of the mechanism of deformation of such configurations will be complicated indeed.

Crystallization may be increased by stretching so that when this occurs the resistance to further stretching by creep should be increased. Since crystallites in polymers are usually surrounded by regions of amorphous structure having much lower creep resistance than the crystallites it is probable that creep deformation of small magnitude in crystalline polymers is largely due to mobility of the amorphous regions—the crystallites remaining substantially elastic.

As suggested by Alfrey (1) flow even in the amorphous regions will tend to be inhibited by the presence of crystallites since the crystallites are composed of segments of polymer chains whose other segments are found in the amorphous phase and in other crystallites. Thus a space network is formed with attendant restriction of mobility similar to that described in the following section on space polymers.

The effect of plasticizers (1) is to separate the polymer molecules so that the strength of the secondary bond forces between polymer chains is reduced. Thus a greater degree of mobility of polymer chains is available, the tendency to crystallize is greatly reduced, and an increased tendency to creep is found.

Crystallization is inhibited if not prevented altogether by structural changes which reduce the mobility of molecular segments—such as in the formation of the space networks described below.

Space Polymers

Three-dimensional network polymers such as phenol-formaldehyde are much more rigid and resistant to creep than linear polymers owing to the three-dimensional network formed by strong primary bonds. The creep of small magnitude that does occur in such polymers is probably the result of relative movements of those segments of the network which are not rigidly held by primary bonds but by secondary bonds. This mobility is exhausted by relatively small creep strains in tension and brittle fracture follows. Under certain conditions of temperature and stress a difference in the influence of primary and secondary bonds may be observed. For example, in compression at elevated temperature creep by a flow mechanism involving secondary bonds may occur until the space network of primary bonds is distorted to such an extent that most of the load has been transferred to the primary bonds. Under this condition the rate of creep is markedly reduced (5). Since the applied load is compression, rupture (if it occurs) must be due to lateral expansion or diagonal slip. In either case the axial stress required to cause rupture is much higher than under tensile loading.

Some linear polymers may be made to acquire some of the desirable features of three-dimensional network polymers (less creep, for example) without some of the undesirable features, such as a tendency for brittleness, by imparting a three-dimensional structure. This is accomplished in some polymers by cross linking the linear chains periodically by one of several processes. This cross linking leaves portions of the chains bound to each other by weak secondary forces, but ties them together at other points by strong primary bonds. The resulting behavior is similar to that of the three-dimensional network polymer except that the extent of the mobile regions is greater, hence greater flexibility and less creep resistance results.

Reinforced Plastics

Creep of reinforced plastics is very greatly influenced by the creep characteristics of the reinforcing material. The reinforcing may consist of fabric or matts or flakes of natural or synthetic polymeric materials, glass, or asbestos. In a reinforced plastic the chief function of the plastic resin is to bind the reinforcing fibers together making it possible for the reinforced plastic to function as a unit rather than as an agglomeration of individual fibers. Thus the resin must serve to distribute the stresses among the individual fibers. In so doing the plastic resin is itself subjected to stress and therefore may creep for the same reasons described above. Actions probably involved in creep of reinforced plastics are the following: (a) creep of the reinforcement; (b) gradual straightening of segments of reinforcing fibers. Such straightening requires simultaneous creep of the resin restraining the fibers in their initial configuration; (c) creep of the resin in regions in which it is highly stressed in transferring stress from fiber to fiber as in a laminate under shear parallel to the lamination; (d) gradual rupture of the bond between resin and fibers with attendant slip of the released portion of fibers relative to the resin and other fibers; and in late stages (e) rupture periodically, randomly, and at an increasing rate of those individual fibers which become subjected to a higher stress for a longer time than they are able to accommodate.

Mechanical Models of Time-sensitive Behavior (Viscoelastic)*

Mechanical models of various sorts have been proposed for more than a hundred years to describe the behavior of materials presumed to consist of elastic and viscous components or elastic and viscous phases (1, 6, 7). In plastics the former corresponds to the elastic deformation of high energy bonds and the latter to the effect of flow of molecular segments by means of exchange of low energy bonds between atoms. It is common practice to represent the elastic phase as a linear spring of modulus E and the viscous phase as a dashpot filled with a fluid of vis-

* A portion of this section has been taken from the author's chapter in reference (7) with the permission of the Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization.

cosity η. Such models have been employed in several combinations and the mechanical behavior under prescribed loads or deformations derived. Two basic combinations may be recognized: the Maxwell unit consisting of a linear spring and dashpot in series, and the Kelvin unit consisting of a linear spring and dashpot in parallel. The behavior of the Maxwell unit and the behavior of a four-element model consisting of a Maxwell and a Kelvin unit in series will be considered briefly.

Maxwell Unit

From the definitions of elasticity and viscosity the following differential equation governing the mechanical response of the Maxwell unit may be derived:

$$d\epsilon/dt = (1/E)d\sigma/dt + \sigma/\eta \,, \quad 1$$

where ϵ is the strain (deformation of the unit), σ is the stress (force on the unit) and t is the time. The stress σ, strain ϵ and modulus E employed in Eq. 1 (and others to follow in this section) are for normal stresses. The equations could be written for shear stresses equally as well.

For stress relaxation at constant strain ϵ_1 Eq. 1 yields

$$\sigma = \sigma_1 \exp(-Et/\eta) \,, \quad 2$$

where $\sigma_1 = E\epsilon_1$ is the initial stress. As shown in Fig. 1 the stress according to Eq. 2 starts decreasing with a finite (not infinite) rate, and the rate decreases continuously as the stress approaches zero asymptotically. This behavior approximates that of some real materials, except for the initial rate. Assuming that the stress decreased continuously at the initial rate the time t_R to reach zero stress is called the relaxation time of the Maxwell unit; and the corresponding stress given by Eq. 2 is e^{-1} of the initial stress σ_1, where e is the natural base of logarithms.

For creep at constant stress Eq. 1 predicts

$$\epsilon = \sigma/E + \sigma t/\eta \,. \quad 3$$

As shown in *Figure 1*, this behavior is a time-independent deformation σ/E followed by a continuous deformation proceeding at the constant rate σ/η. This behavior is approximated by some real materials.

Upon removal of the load the strain is in part recovered instantaneously and there is no gradual recovery, such as is usually observed in real materials.

Maxwell and Kelvin Units in Series (four-element model)

This combination is capable of representing the behavior of real materials somewhat better than any combination of two or three elements in that it predicts that creep increases indefinitely but at a decreasing rate. The creep equation for this model has the form

$$\epsilon = \sigma/E_1 + \sigma t/\eta_1 + \sigma[1 - \exp(-E_2 t/\eta_2)]/E_2 \,, \quad 4$$

where the subscript 1 refers to the Maxwell unit and the subscript 2 refers to the Kelvin unit. The behavior described by this equation is shown in *Figure 2*. As suggested by the figure the elastic element E_1 contributes a constant strain σ/E_1; the viscous element of viscosity η_1 contributes a deformation $\sigma t/\eta_1$ which continues at a constant rate even after all other units have ceased to deform further; and the Kelvin unit E_2, η_2 contributes a strain $\frac{\sigma}{E_2}\left[(1 - \exp(-E_2 t/\eta_2)\right]$ whose rate decreases toward zero at large values of time.

After removal of load the four-element model discloses a gradual recovery asymptotic to a permanent extension which is never recovered after removal of load.

When subjected to a constant strain (relaxation test) the four-element model undergoes a relaxation of stress which proceeds gradually to zero in infinite time.

Complex Mechanical Models

The above models will not accurately describe the behavior of many plastics over wide ranges of the variables—especially for both large and small values of time—even when no significant change in structure of the material occurs during the action. The models described above have only one relaxation time. However, if the structure of plastics is considered it seems reasonable to expect more than one relaxation time to be operative. It is known that the length, kinks, loops and curls of the chain molecules in plastics are of all sizes. Hence it seems reasonable to expect that short kinks in the chain will straighten out or untwist more easily than longer waves or loops. Thus a different relaxation time may be associated with each size of structural configuration.

A model having two relaxation times will have a different shape response curve from a model having one relaxation time. More than two relaxation times would usually be involved so that the behavior might be represented by several Maxwell units of different relaxation times in parallel or several Kelvin units and one Maxwell unit in series (see *Figure 3*).

The creep of the latter model is the sum of the extensions of each Kelvin unit and the one Maxwell unit or

$$\epsilon = (\sigma/E) + (\sigma t/\eta) + \sigma \sum_{i=1}^{r} [1 - \exp(-E_i t/\eta_i)]/E_i \,. \quad 5$$

Actually the creep of either complex model may be represented by an equation of the form of Eq. 5. It may be more convenient in analysis to replace the last term of Eq. 5 by an integral representing a continuous distribution of relaxation times (8).

Another method of achieving a more realistic description of material behavior is through employing elements in the models which have a nonlinear response to stress.

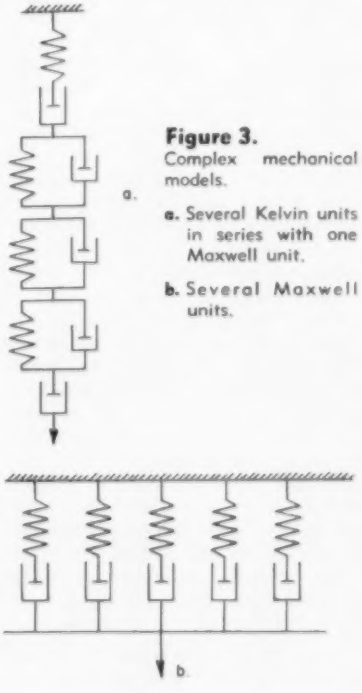


Figure 3.
Complex mechanical models.

a. Several Kelvin units in series with one Maxwell unit.

b. Several Maxwell units.

Memory Effect

The memory effect is a phenomenon in plastics which may be described in terms of the behavior of a model having two or more relaxation times. When the model has two relaxation times, one short, the other long, the following behavior may be predicted. Hold the model (or plastic) at a constant deformation for a long time such that both relaxation times are exceeded. Then remove the first deformation and deform in the opposite sense for a short time such that the short relaxation time will have been exceeded. Then release. Following release of constraint the recovery of the element having the short relaxation time will be rapid, but the element having the long relaxation time will still be recovering

from the first deformation.

Thus recovery first proceeds rapidly in one direction, then stops and proceeds more slowly back in the other direction, that is, in the direction of recovery from the effect of the first load.

The Activation Energy Theory For Stress and Temperature Influence

The activation energy theory concerns the rate of activation of movement of one portion of the molecular structure of the material past the barriers to this movement. In metals it is considered that the prime mechanism of deformation which is activated is the movement of dislocations along lattice planes past barriers, such as foreign or interstitial atoms, etc. In plastics it is considered that the mechanisms of deformation which are activated are: (a) the relative motion (sliding) of segments of molecular chains by a process of place change of atoms bound by secondary forces (van der Waals' forces), (b) disruption of secondary cross bonds, (c) disruption of primary cross bonds.

Each of these movements may be precipitated if the energy available at any instant becomes greater than the free energy barrier for such action. According to the rate process theory (9) the frequency ν with which the action will be activated is given by

$$\nu = (kT/h) \exp(-\Delta f^\circ/kT) \quad 6$$

where k and h are universal constants called Boltzmann and Planck constants, respectively, T is the absolute temperature and Δf° is the free energy of the barrier.

In the absence of shear stress τ the frequency of jumps past the barrier in the positive and negative directions will be equal and no net deformation will occur. If a shear stress is applied the energy barrier for a positive jump will be reduced by the amount of the work done by the stress, whereas the energy barrier for a negative jump will be increased. The net jumps in the positive direction will be the difference between positive and negative jumps. In this sum the stress term appears in the form $e^x - e^{-x}$. Thus the net frequency becomes

$$\nu = \frac{2kT}{h} \exp(-\Delta f^\circ/kT) \sinh \frac{\lambda\tau}{2kT} \quad 7$$

where λ is the average distance, in the direction of stress, between equilibrium positions in successive jumps. The flow rate is proportional to the net frequency of jumps. If to this flow term is added the contribution of the elastic strain rate an expression in the following form is obtained:

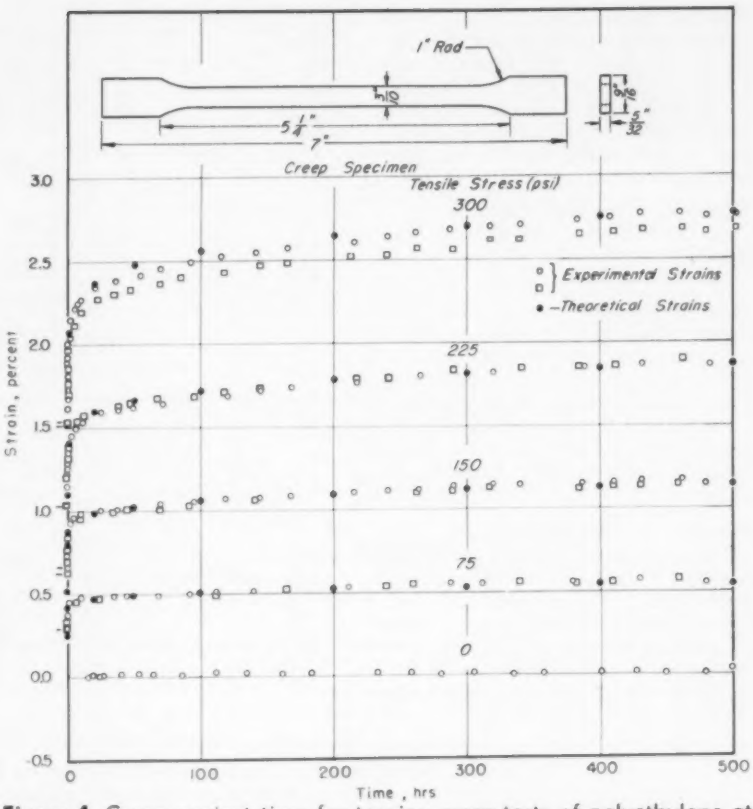


Figure 4. Creep against time for tension creep tests of polyethylene at constant load. Temperature 77°F, relative humidity 50 per cent. First test point for each specimen in a series of creep tests is indicated by a short dash line. The black points were computed from Eq. 11 using the values of constants given in Table I. (from Findley and Khosla in J. Soc. Plastics Engrs., 1956)

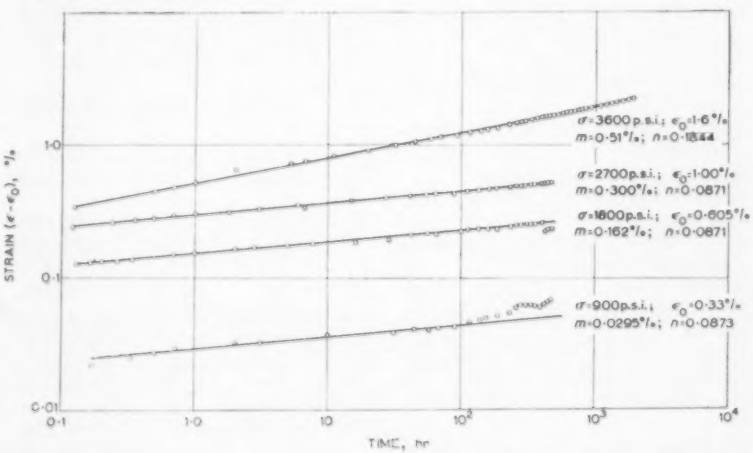


Figure 5. Evaluation of constants ϵ_0, m and n for polymonochlorotrifluoroethylene in crystalline form for creep at 77°F and 50 per cent relative humidity (from Findley and Khosla, J. Soc. Plastics Engrs., 1956)

$$\frac{d\gamma}{d\tau} = \frac{1}{G}\frac{d\tau}{dt} + 2a\frac{kT}{h} \exp(-\Delta f^\circ/kT) \sinh \frac{\lambda\tau}{2kT} \quad 8$$

where γ is the shear strain, G the shear modulus and a is a constant. For constant temperature and small values of $\lambda\tau/2kT$ it will be observed that Eq. 8 reduces to the form of the

Maxwell equation, Eq. 1.

It has been suggested that the behavior of plastics may be described by three equations of the form of Eq. 8 but having different constants, and corresponding to the three mechanisms of deformation listed in the first paragraph of this section.

Power Law for Time Influence

It has been observed that the empirical power function of time

$$\epsilon = \epsilon_o + m(t/t_o)^n \qquad 9$$

describes tension creep of many different rigid plastics (10-12) with good accuracy over a wide range of values of time. In Eq. 9 ϵ_o and m are functions of stress, n is independent of stress and t_o is a constant conveniently taken equal to unity. All these quantities are probably functions of temperature.

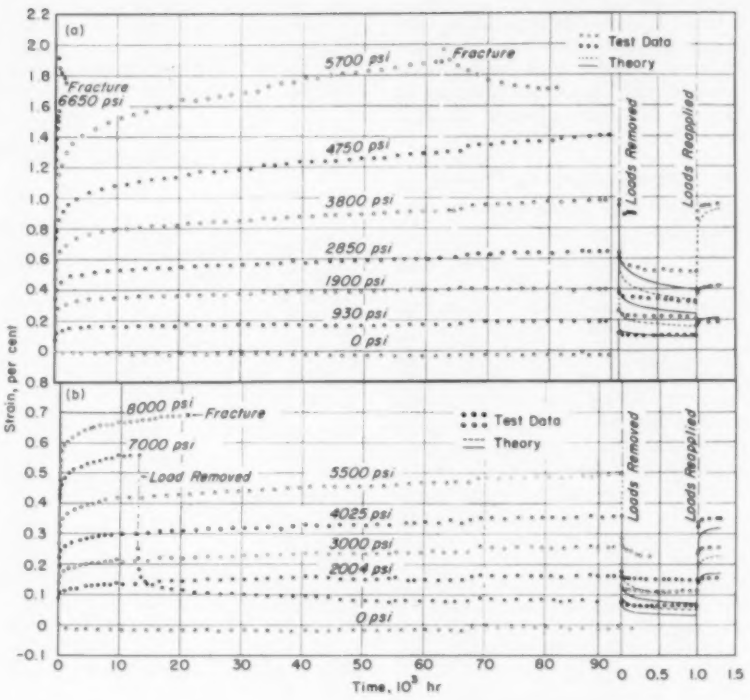


Figure 6. Rectilinear plot of Strain versus Time, Including Creep, Recovery and Reload for Laminates at 77°F and 50 Per Cent Relative Humidity. (a) Grade C canvas laminate. (b) Parallel-laminated paper laminate. (from Findley and Peterson, reference 12)

Table I. Constants for Creep Equation, Including Stress Functions

$\epsilon = \epsilon_o' \sinh \sigma/\sigma_\epsilon + m'(t/t_o)^n \sinh \sigma/\sigma_m$

Material	Temp., °F	Relative humidity, %	n, dimensionless	ϵ_o', in. per in.	m', in. per in.	σ_ϵ, psi	σ_m, psi	Reference
Polyethylene	77	50	0.0890	0.01350	0.00397	400	185	(11)
Polymonochlorotri-fluoroethylene	77	50	0.0872*	0.00810	0.00099	2,600	1,475	(11)
Polyvinyl chloride	77	50	0.3109	0.01150	0.00018	6,000	2,100	(11)
Polystyrene	77	50	0.525	0.048	4.098×10^{-6}	20,000	650	(15)
Melamine-resin glass fabric laminate**	77	50	0.0186	0.00575	0.00575	35,000	35,000	(26)
Silicon-resin glass fabric laminate**	77	50	0.0283	0.00203	0.00203	7,800	7,800	(26)
Grade C canvas laminate	77	50	0.1183	0.001875	0.001875	4,000	4,000	(12)
Parallel laminated paper laminate	77	50	0.114	0.00184	0.002019	6,000	14,000	(12)
Cross laminated paper laminate	77	50	0.0763	0.00315	0.001176	12,000	8,000	(12)
Asbestos laminate	77	50	0.267	0.00311	0.0001271	4,000	2,400	(12)
Polyester-resin, 181 glass fabric	73	50	0.090	0.0034	0.000445	15,000	14,000	(27)
Polyester-resin, 181 glass fabric	73	immersed in water	0.210	0.0330	0.000170	80,000	13,000	(27)
Polyester-resin, glass fiber mat	73	50	0.190	0.0067	0.0011	8,500	8,500	(27)
Epoxy resin, 181 glass fabric	73	50	0.160	0.0057	0.000500	25,000	50,000	(27)
Epoxy resin, 181 glass fabric	73	immersed in water	0.220	0.0250	0.000055	80,000	11,000	(27)
Polyester resin, No. 1000 glass fabric	73	50	0.100	0.0015	0.000220	10,000	8,600	(27)
Polyester resin, No. 1000 glass fabric	73	immersed in water	0.190	0.0280	0.000108	80,000	6,500	(27)
Polyester resin, glass woven roving	73	50	0.200	0.0180	0.00100	40,000	22,000	(27)
Polyester resin, glass woven roving	73	immersed in water	0.230	0.0206	0.01460	40,000	40,000	(27)

* For stresses σ = 900, 1800, 2700 p.s.i., n = 0.0872 while for σ = 3600 p.s.i., n = 0.184.
** In analysis of these tests it was assumed, but not proven, that $\epsilon_o' = m'$ and $\sigma_\epsilon = \sigma_m$.

In *Figure 4* is shown a set of creep curves which are typical of many plastics. It will be observed that the rate of creep is very rapid immediately after loading and decreases continuously with time. The rate of creep $d\epsilon/dt$ obtained by differentiating Eq. 9 is

$$d\epsilon/dt = mn(t/t_o)^{n-1}. \qquad 10$$

For $n < 1$, which is the case for plastics, it is evident that $d\epsilon/dt$ is infinite at $t = 0$ and decreases continuously with time. It may be shown from Eq. 9 that log $(\epsilon - \epsilon_o)$ is a linear function of log t, with a slope of n. Thus creep data plotted as log $(\epsilon - \epsilon_o)$ vs. log t should describe straight parallel lines, as illustrated in *Figure 5*, for all but one test of polymonochlorotrifluoroethylene. The highest stress employed in those tests produced crazing, which may be the cause of the higher slope of the top curve in *Figure 5*.

It may be observed that Eq. 9 describes the time influence in creep better than the other simple relations, described above, and over a wider range of time. A thoroughly satisfying theoretical interpretation of this relation is, however, lacking. It may be considered that Eq. 9 is the response of a system of viscoelastic elements having a distribution of relaxation times.

It has also been observed (11) that the hyperbolic sine function predicted by Eq. 8 satisfactorily describes the stress dependence of m in Eq. 10 for moderate values of σ. A hyperbolic sine, with different constants, also describes the stress dependence of the time-independent term ϵ_o in Eq. 9 for moderate values of σ. Thus Eq. 9 may be written as follows:

$$\epsilon = \epsilon_o' \sinh \sigma/\sigma_\epsilon + m'(t/t_o)^n \sinh \sigma/\sigma_m, \qquad 11$$

where ϵ_o', σ_ϵ, m', n, σ_m are constants which may vary with temperature.

The values of these constants are given for a variety of rigid plastics and laminates in *Table 1*. The wide range of values of the exponent n is to be noted.

It may be observed that the time-independent term given by Eq. 11 includes the linear case as well as non-linear. When σ_ϵ is sufficiently large compared to the values of σ involved sinh σ/σ_ϵ approaches σ/σ_ϵ. Also Eq. 11 includes the case of constant creep rate. As shown by Eq. 10 when $n = 1$, $d\epsilon/dt$ is a constant equal to m.

Long-time Creep

Results of creep tests of three plastic laminates are available for testing times of approximately ten years. Results of two of these tests were reported after the first 2,000 hr. as being describable by Eq. 9. These tests were continued for about 10 years with the results shown in *Figure 6*. Subsequently the results obtained for 10 years were compared with the predictions of Eq. 9 using the constants determined from the first 2,000 hr. The prediction based on Eq. 9 was found to be very satisfactory as shown in *Figure 7* in which the straight lines represent Eq. 9 using the constants obtained from the first 2,000 hr. of testing.

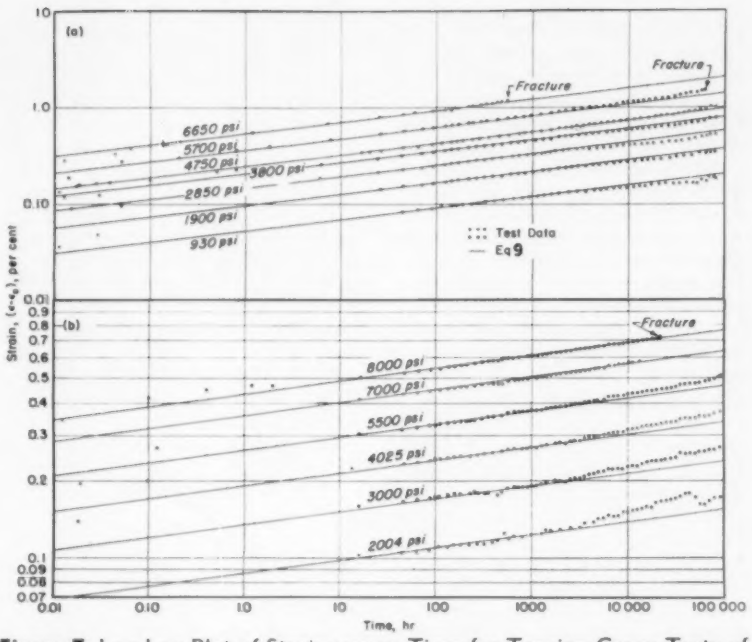


Figure 7. Log-Log Plot of Strain versus Time for Tension Creep Tests of Laminates at 77°F and 50 Per Cent Relative Humidity. (a) Grade C canvas laminate (strains corrected for shrinkage). (b) Parallel-laminated paper laminate (strains corrected for shrinkage). (from Findley and Peterson, reference 12)

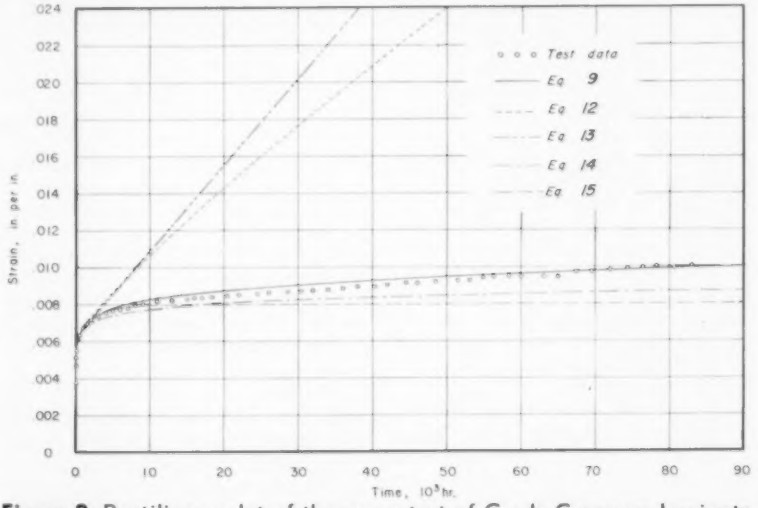


Figure 8. Rectilinear plot of the creep test of Grade-C canvas laminate at 3800 psi, together with the prediction of several theories based on the best representation for the first 2000 hours. (from Findley and Peterson, reference 12)

A comparison of the predictions of several creep relations is shown in *Figure 8* together with one of the tests from *Figure 7*. In addition to Eq. 9 the following equations were considered in *Figure 8*:

$$\epsilon = \epsilon_o + A \log_e t + Bt \qquad 12$$

$$\epsilon = \epsilon_o + A(1 - e^{-ct}) + Bt \qquad 13$$

$$\epsilon = \epsilon_o + A \log_e t \qquad 14$$

$$\epsilon = \epsilon_o + A\,(1 - e^{-Bt}) \qquad 15$$

where ϵ is the strain, t the time, e the base of natural logarithms and ϵ_o, A, B, C are constants for a given stress, material and temperature. Eq. 12 and 14 are empirical forms, Eq. 13 represents the creep of a Maxwell and Kelvin unit in series and Eq. 15 represents the creep of a Kelvin unit in series with an elastic element. The constants in all of these equations were selected to yield the best agreement with the first 2,000 hr. of data. Of the five equations Eq. 9 yielded the most accurate prediction of long-time creep.

Creep Under Varying Stress

Creep under varying stress may be described by means of viscoelasticity through such models as described above. However, the simple models do not describe actual behavior satisfactorily and complex models are difficult to work with. Hence other concepts have also been proposed including the theories of the mechanical equation of state, strain and time hardening, and the principle of superposition.

Mechanical Equation of State*

A mechanical equation of state for solids (13) is analagous to the thermodynamic equation of state for gases. It considers the stress to be a function of the simultaneous values of strain, strain rate and temperature, and independent of the path followed by the variables in arriving at a given point. If the structure of the material is altered during the action it is evident that the mechanical equation of state will not apply accurately. Since it is known that some possible paths of the variables, temperature for example, will produce irreversible changes in structure of the material the allowable paths must be restricted to those which produce negligible changes in structure.

Examination of creep tests with varying stress such as shown in *Figure 9* shows a reasonable agreement with the mechanical equation of state for increasing loads, but not for decreasing loads. In the latter case the sign of the strain rate is incorrectly predicted under some conditions.

Strain and Time-Hardening Theories

Equation 11 indicates that at a constant stress σ the time dependent part ϵ_p of the total strain ϵ is given by

$$\epsilon_p = m'\,(t/t_o)^n \sinh \sigma/\sigma_m. \qquad 16$$

Equation (16) states that there exists a single value of ϵ_p for each value of σ and t. However, as pointed out by Roberts (14) and others ϵ_p is not a single valued function of σ and t for many real materials since by changing the stress history many values of ϵ_p can be made to occur at the same values of σ and t. Compare sequence D with sequences A, B and C for $\sigma = 3{,}600$ psi and $t = 1{,}500$ hr. in *Figure 9b* for example. Thus Eq. 16 is not a general relation. It may, however, be viewed as the result of an integration at constant stress of an unknown differential creep law between time limits of 0 and t and strain limits of 0 and ϵ_p.

To obtain the differential creep law a creep equation is differentiated at constant stress. However, this yields an infinite number of solutions (14). If for example the nth root of both sides of Eq. 16 is taken before differentiation the following is obtained:

$$\left.\frac{d\epsilon_p}{dt}\right|_{\sigma\,=\,\text{const}} = \frac{n\,(m' \sinh \sigma/\sigma_m)^{1/n}}{(\epsilon_p)^{(1/n)-1}}. \qquad 17$$

A direct differentiation yields

$$\left.\frac{d\epsilon_p}{dt}\right|_{\sigma\,=\,\text{const}} = m'\,nt^{n-1} \sinh \sigma/\sigma_m\,. \qquad 18$$

If both sides of Eq. 16 are squared and then differentiated

$$\left.\frac{d\epsilon_p}{dt}\right|_{\sigma\,=\,\text{const}} = \frac{n\,(m' \sinh \sigma/\sigma_m)^2\,t^{2n-1}}{\epsilon_p}. \qquad 19$$

Equations 17-19 are different so their integration will yield different results. The problem is to determine the correct one of the infinite number of possible differential equations.

Equation 17 describes the time dependent strain rate as a function of strain ϵ_p; thus it may be thought of as a strain-hardening law. Similarly Eq. 18 then is a time-hardening law, and Eq. 19 is a combined strain- and time-hardening law. It was observed (15) from tests such as shown in *Figure 9* that the strains predicted from the strain-hardening theory were the closest to the test data of the three theories represented by Eq. 17-19. However, all three of these theories fail to predict the negative creep rate observed in *Figure 9* following a decrease in stress. They all predict positive creep rate regardless of

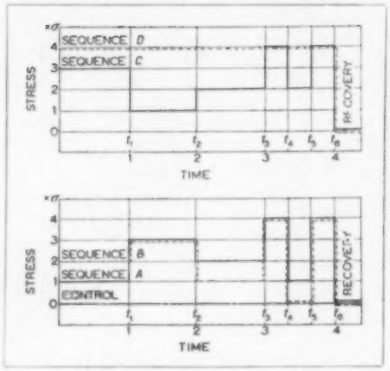
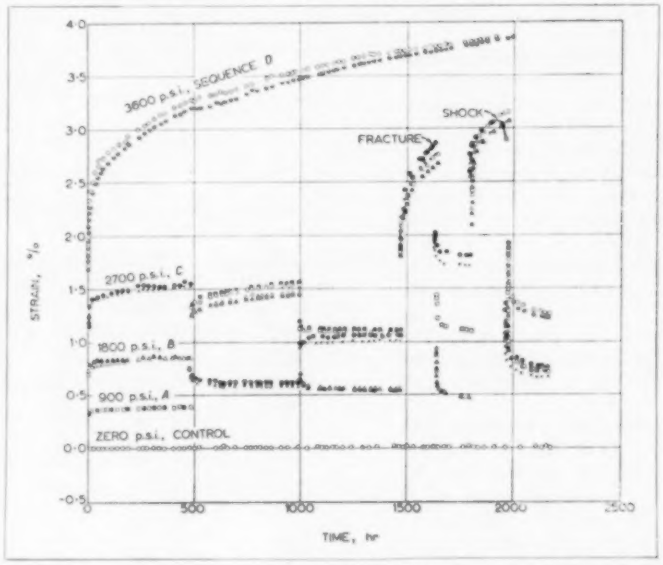


Figure 9a. Program of stress vs. time for creep tests with different stress sequences.

Figure 9b. Creep curves for polymonochlorotrifluorethylene under stress sequences shown above. Temperature 77°F, relative humidity 50 per cent (from Findley and Khosla, reference 15)



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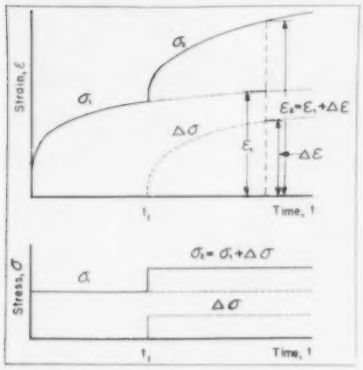

Figure 10. The superposition principle as applied to creep when the stress is changed by an increment $\Delta\sigma$ at time t_1

whether the stress was increased or decreased. Thus, these equations are not reliable—at least for abrupt changes in stress.

The Superposition Principle*. This principle seems to produce the best results for predicting creep of plastics under varying load. According to the superposition principle, if various loads P_1, P_2 . . . are applied at times θ_1, θ_2 . . . respectively, previous to a given instant t, then the deformation of the material at time t due to the several previously applied loads is equal to the algebraic summation of the deformations which would have been produced independently by each applied load.

The superposition principle is usually considered to refer to systems in which the deformations are linear functions of the load. Since this is not the behavior observed for plastics as described by Eq. 11 a modified superposition principle may be approximated for Eq. 11 as follows. For a single instantaneous change in stress from σ_i to σ_f at time t_1 the creep for time t greater than t_1 may be expressed as

$$\epsilon = \epsilon_o' \sinh \sigma_i/\sigma_r + m't^n \sinh \sigma_i/\sigma_m + \epsilon_o' \sinh (\sigma_f - \sigma_i)/\sigma_r + m'(t - t_1)^n \sinh (\sigma_f - \sigma_i)/\sigma_m . \quad 20$$

The first two terms represent the creep resulting from a stress σ_i continuously applied during the entire time; and the last two terms represent the creep resulting from the change in stress $(\sigma_f - \sigma_i)$ applied as an independent stress starting at time t_1. The modified superposition principle as illustrated by Eq. 20 cannot be expected to yield accurate results under all conditions since superposition is strictly applicable only to functions which are linear in stress. The smaller the stress ratios, σ_i/σ_r, etc., in Eq. 20 the more nearly linear the stress functions and hence the more accurate the predictions of Eq. 20, according to the superposition principle. The superposition principle is illustrated diagrammatically for a single change in load in *Figure 10*.

The superposition principle predicts the correct sign of creep rate following a decreasing load step. Also the magnitudes of creep strains predicted by this principle agree with the observations in tests such as *Figure 9b* better than the other methods of prediction considered above.

In order to generalize to any history of stress the superposition principle may be expressed as follows for creep (16, 17) under variable stress $\sigma(t)$:

$$\epsilon(t) = F[\sigma(t)] + \int_o^t \dot{H}(t - \tau)\, K[\sigma(\tau)]\, d\tau , \quad 21$$

where the integration extends over the entire time from the first stressing, $F[\sigma(t)]$ is the instantaneous strain due to stress at time t, and $\dot{H}(t - \tau)$ and $K[\sigma(\tau)]$ are arbitrary functions chosen to satisfy known effects. $\dot{H}(t - \tau)$ is called the creep memory (or heredity) function, $H(t)$ is the creep function and $\dot{H}(t)$ is the creep rate. The Boltzmann superposition principle is strictly described by Eq. 21 only when the functions $F[\sigma(t)]$ and $K[\sigma(t)]$ are linear in stress.

A similar function based on superposition for relaxation under variable strain $\epsilon(t)$ is expressed as

$$\sigma(t) = f[\epsilon(t)] - \int_o^t \dot{h}(t - \tau)\, k[\epsilon(\tau)]\, d\tau , \quad 22$$

where, as before, the integration extends over the entire time from the first stressing; $f[\epsilon(t)]$ is the instantaneous stress due to strain at time t and $\dot{h}(t - \tau)$ and $k[\epsilon(\tau)]$ are arbitrary functions. $\dot{h}(t - \tau)$ is called the remembrance function, and $h(t)$ is the relaxation function. Again the Boltzmann superposition principle is strictly described by Eq. 22 only when the functions $f[\epsilon(t)]$ and $K[\epsilon(t)]$ are linear in strain. A relation between the creep and the relaxation function for Boltzmann superposition has been reported by Gross (8, 17).

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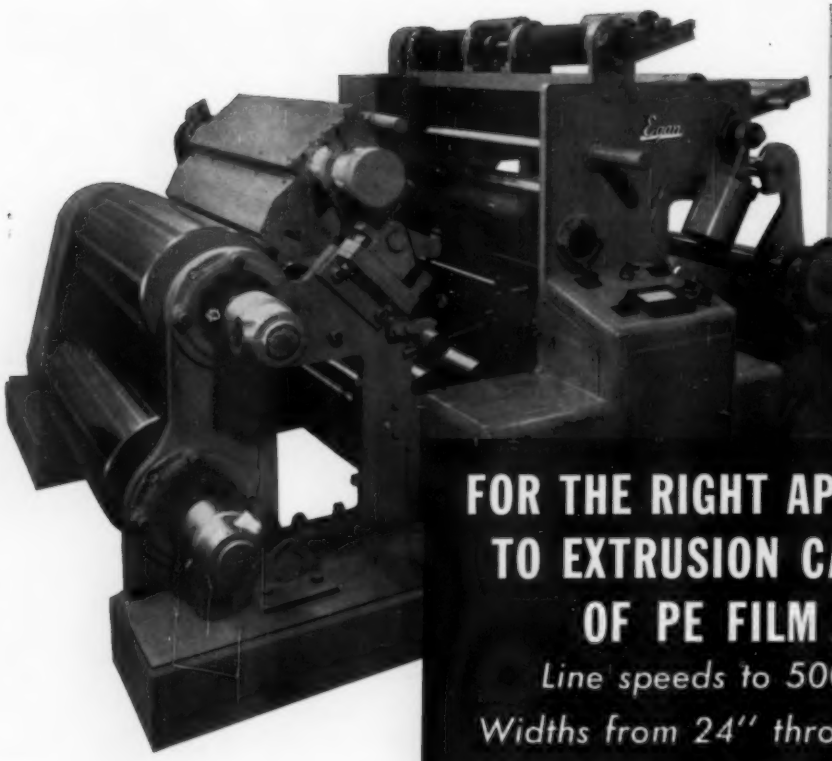
Part II—Next Month

*Footnote page 59



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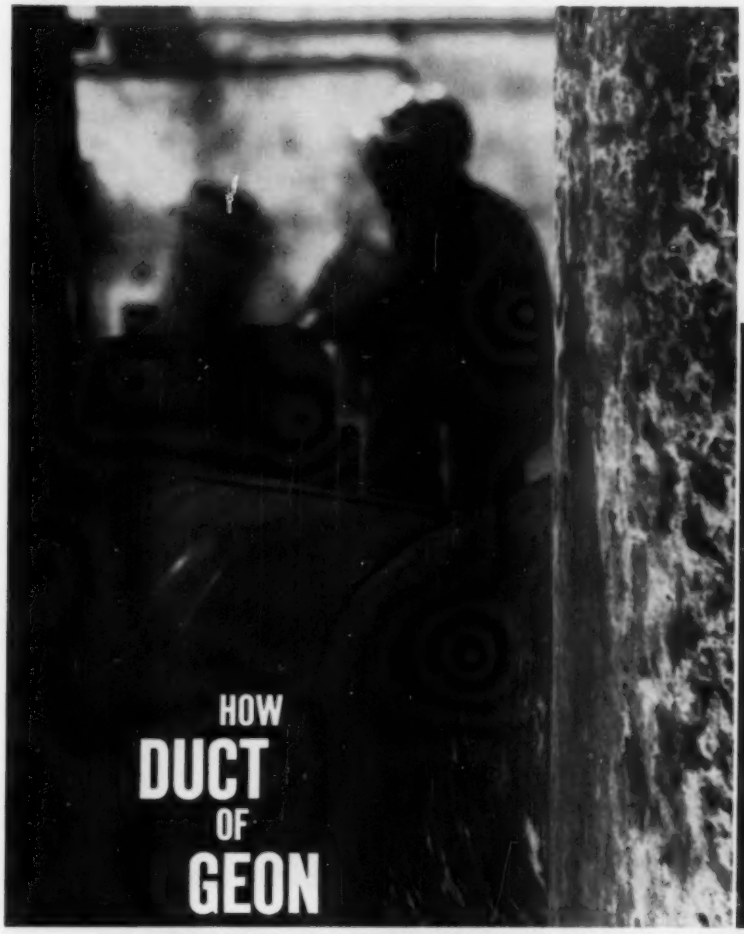
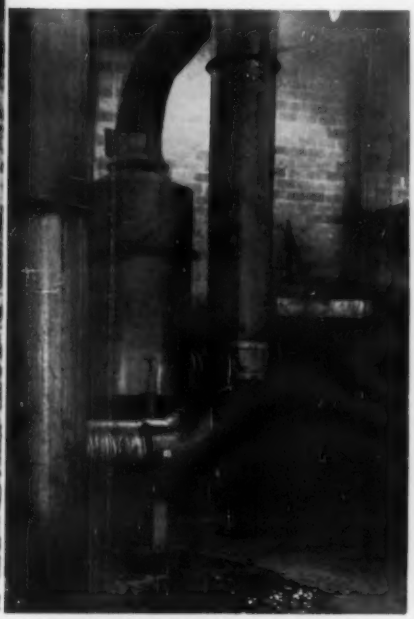


The large duct shown here was fabricated of Geon vinyl by Colonial Plastics Mfg. Co. through their distributor, Gould-Kramer, Inc., Cleveland, Ohio. B.F.Goodrich Chemical Company supplied the Geon vinyl.



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For more information on products made of Geon vinyl—or on this versatile material itself—write Dept. GM-1, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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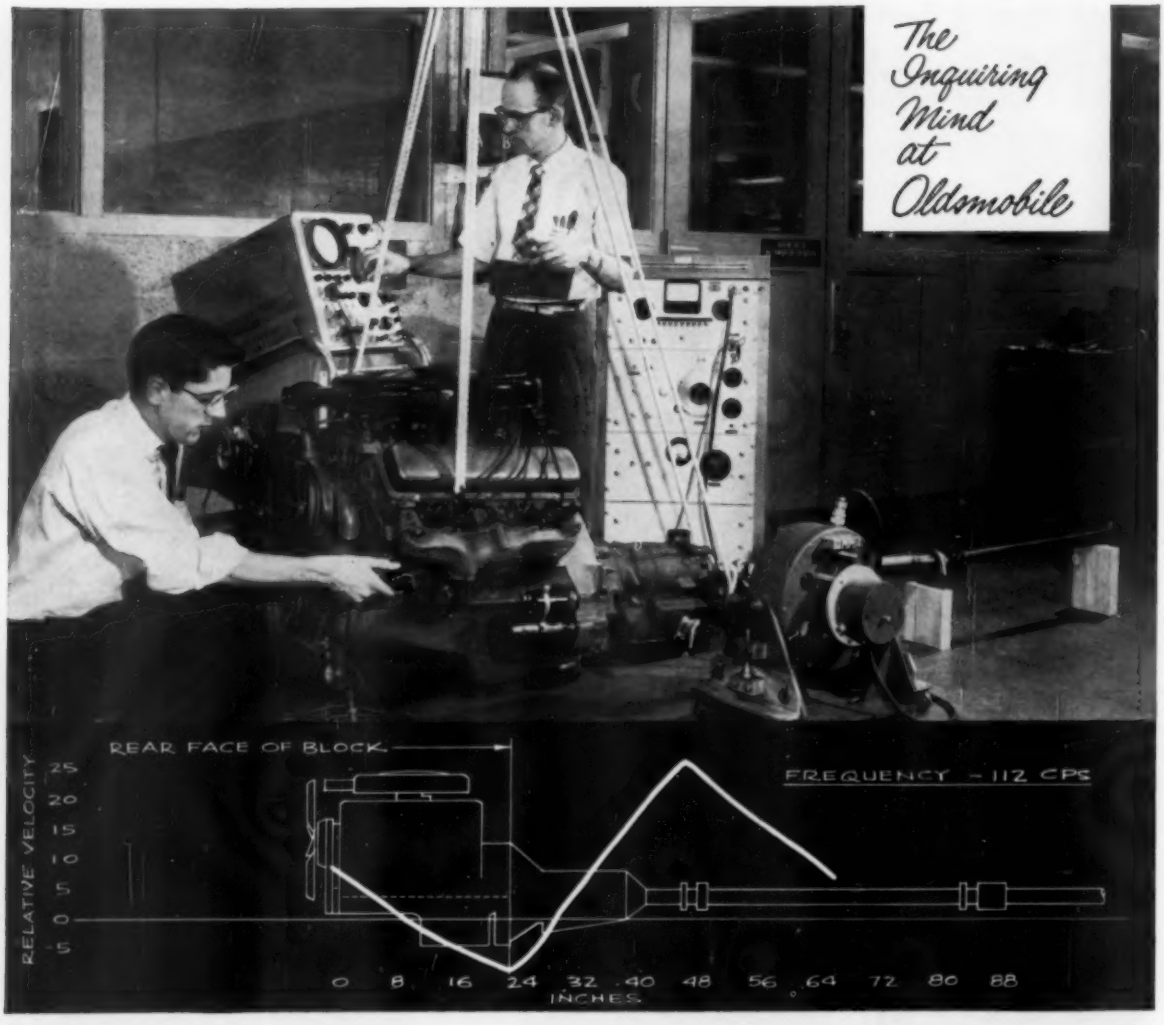

no. 11 OF A SERIES

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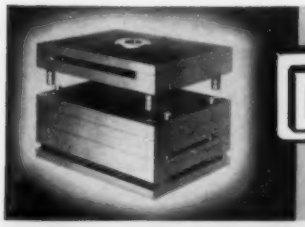

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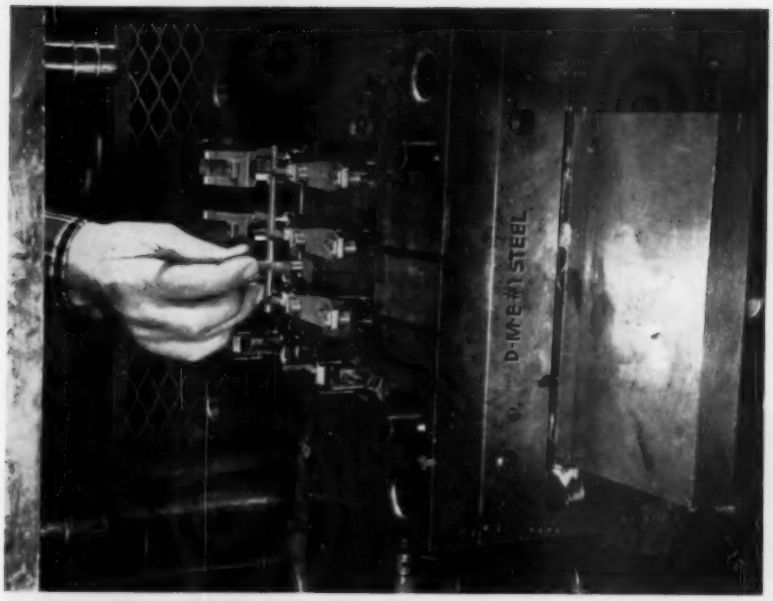

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59-A

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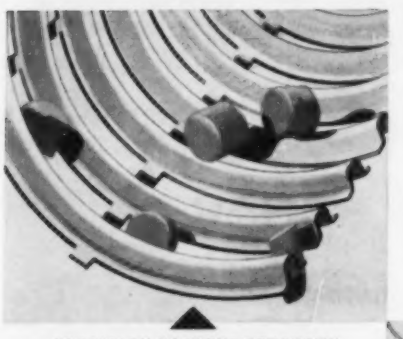
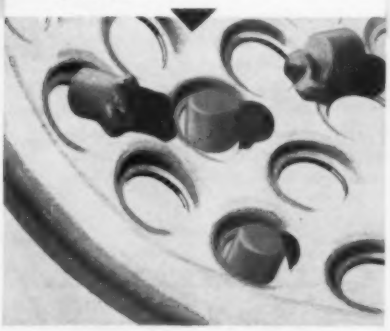


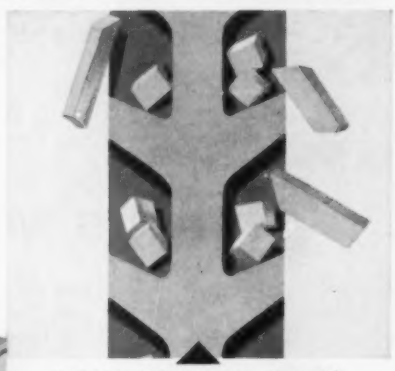
PRECISION GRADERS SEPARATE MATERIAL BY THICKNESS

For sizing and separating free-flowing granular materials by *thickness*, Carter Precision Graders use revolving cylinders with slotted perforations. Material placed in these cylinders is upedged and presented to the slots in an edgewise position. The thinner pieces pass through, and the thicker pieces pass over and are conveyed to the end of the machine.

CARTER GRADERS ALSO SIZE AND SEPARATE BY WIDTH

For *width* sizing and separating, the Precision Graders use revolving cylinders with round perforations. Material placed in these cylinders is upended and presented to the round perforations in an endwise position. Narrow pieces pass through, and wider pieces pass over for discharge at the end of the cylinder.





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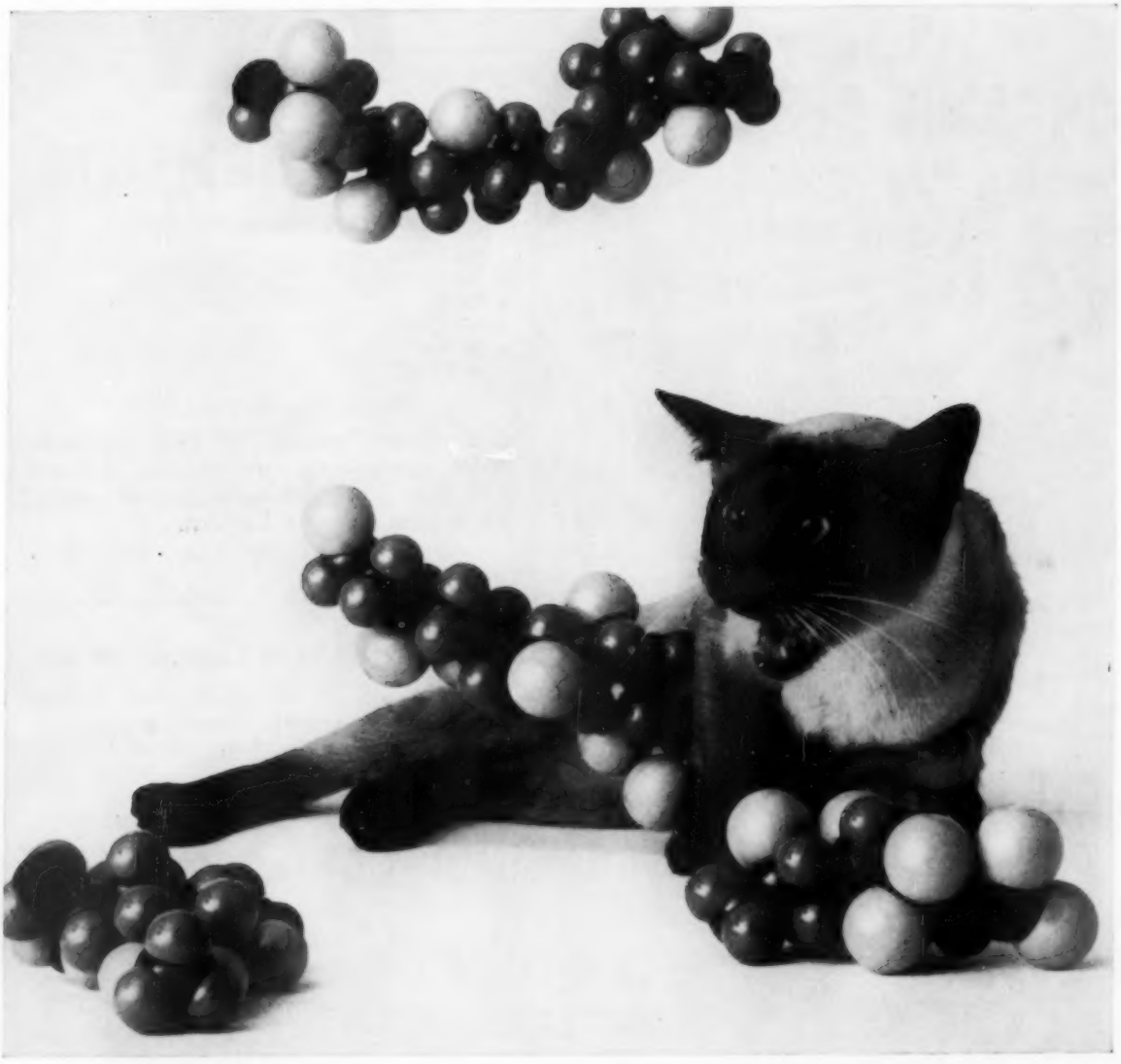

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If, for example, your basic requirement is exceptional heat and light stability, you'll get it consistently, and at less cost, with Argus Mark LL—the most effective vinyl stabilizer on the market today. And for any *special* problems, *Argus gets the answers.*

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SPE JOURNAL

Every Month—the *significant* NEWS
OF PLASTICS ENGINEERING

D. L. Peters and J. N. Scott
Phillips Chemical Co.

The most widely used blow molding techniques employ the extrusion process. These techniques are well adapted to high volume production. However, many potential markets are of low volume (50,000 units or less). High equipment and die costs of the presently used blow molding techniques make unit costs prohibitive on small lot orders. Because of these costs, there has been considerable interest in a technique which will require a minimum investment in equipment and operate at an acceptable production rate. For this reason, several methods of blow molding were investigated, each from the standpoint of producing parts at a low unit cost, especially on relatively small production totals.

Since most injection molders occasionally have idle machine time, a blow molding *technique employing existing injection molding machines* offers substantial savings in capital investment for plasticating equipment.

One process utilizing injection machines is the Granbull blow molding technique. The equipment consists of an injection mold, blowing mandrels and a blowing mold. The process injection molds the parison around a hot blowing mandrel. The blowing mandrel and parisons are then removed from the injection mold and placed in a blowing mold where blowing air is admitted through the mandrels. This process has been used commercially for some time. However, there is considerable art involved.

Another injection blow molding technique recently developed proved to be very successful. Built by our own shop, the apparatus employs the injection cylinder ram for intermittent extrusion of the parison tube. The equipment is basically a hot runner, blowing mold in an injection machine. Since the complete assembly including molds costs only a fraction of extrusion equipment, capital investment is relatively low. As can be seen in *Figure 1*, the equipment consists of three units:

1. A hot runner and die head containing a conventional extrusion mandrel and die bushing for forming the parison tube from which the bottle is blown (detailed in *Figure 2*).
2. The molds and mechanisms for holding and moving the molds (*Figure 2*). This assembly is clamped between the platens of the injection molding machine. A hydraulic cylinder powers the mold half attached to the platen rails of the mold assembly. The other mold half is clamped to the movable platen on the machine and moves with this platen.
3. The control cabinet containing the air valves, air manifold, timers, solenoids and relays necessary for the operational sequences essential to blow molding.

The electrical circuit requires a few wiring changes for an automatic blowing cycle. In normal operation the dies of an injection molding machine close and then the plunger moves forward to inject molten resin. The machine can have this sequence reversed for blow molding, i.e., the plunger can move ahead first, and at a predetermined time the dies will close. After a time delay the dies will open and the sequence can be repeated. This can be done automatically *if* the machine is an automatic machine.

Aluminum, Vega steel, and Kirksite "A" molds have all been satisfactory in blow molding operations. Excellent matching of the cavities has been found to be extremely important in order to prevent "thinning" of the bottle at the parting lines of the mold.

With this equipment in an eight ounce machine, it has been possible to mold with 12 second cycles. The limiting factor is the dry cycle speed of the injection molding machine. All of the cycle time excepting that required to eject the part and re-extrude the parison tube can be used in blowing molding if the machine is properly programmed. As the equipment had only a single cavity mold, production could be increased up to the limit of the plasticating capacity of the machine by use of multi-cavity molds.

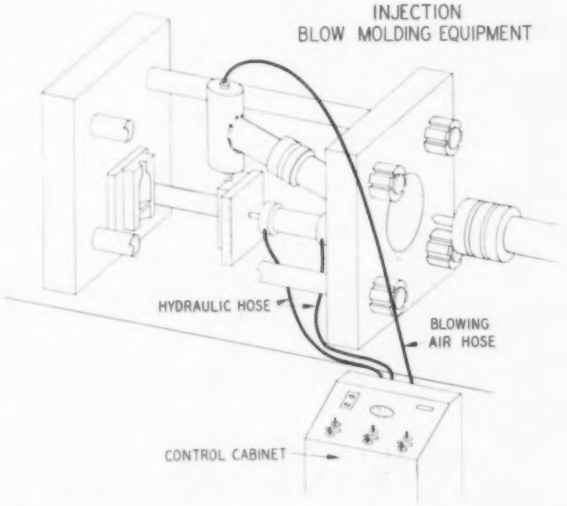

Figure 1. Equipment consists of three units (1) a hot runner and die head, (2) the molds and mechanisms for holding and moving the molds and (3) the control cabinet.

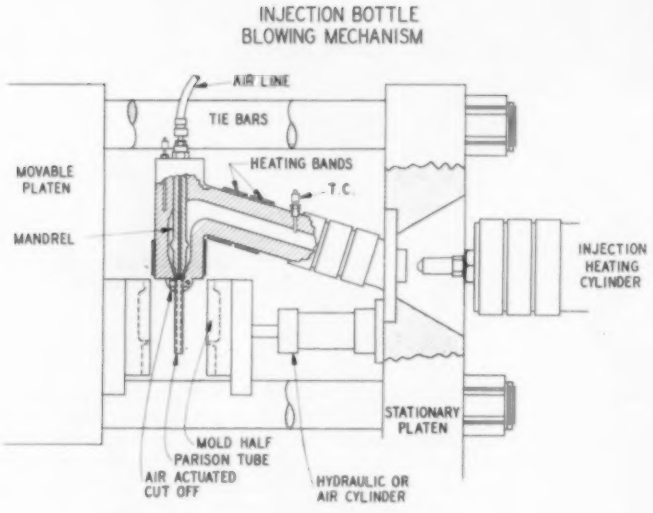

Figure 2. The molds and mechanisms for holding and moving the molds.

Operating conditions for blow molding have not been found to be critical although a relatively narrow range of control settings gave the best results. Conditions used here with a 12 second cycle and 22 mil wall thickness were:

Equipment Part	Range of Conditions	Optimum Condition
Injection machine heating cylinder temperature	380 to 500 F	400 F
Extrusion head temperature	380 to 480 F	380 F
Mold temperature	60 to 225 F	Cold
Blowing pressure	20 to 100 psi	greater than 40 psi

Generally speaking, the extrudate and blown item have smoother surfaces with the higher cylinder and head temperatures. The surface of the parts is also improved with higher mold temperatures. As expected, higher stock and mold temperatures require longer blowing times.

High density polyethylene can be easily blow molded at high production rates. The lower melt index resins (around 0.3) are preferred for most applications, but good parts can also be blown from the higher melt index resins.

Good cooling is needed in the thick walled neck and pinch-off areas of the mold to prevent deformation of the part after ejection. The thinner body section usually does not require efficient channeling. The parting line "match" is actually less critical if this area of the mold warms up during production.

Operations with this particular piece of blow molding equipment have shown the importance of several good design principles:

1. All sharp corners and "dead spots" in the parison extrusion head must be avoided. Any resin "hanging up" will eventually burn and cause vertical lines in the part. The extrusion head should have streamlined passages.

2. "Thinning" of the part at the mold parting lines can be a problem with poorly matched cavities, or with poor mold closures. The thinning occurs because of the slower cooling rate of the polymer that doesn't have intimate contact with the mold surface—the bulk of the parison tube cools more rapidly, thereby shrinking and drawing the bottle thin at all places where the cooling rate is retarded. Although undesirable because of the longer blowing time required, high mold temperatures will compensate for poor mold closures by equalizing cooling and shrinkage rates, thereby increasing the wall uniformity of the item. The correct solution to this problem lies in excellent cavity matching, and subsequent good alignment of the mold halves on the mold platen. A simple, positive system for aligning and locking the mold halves on the mold platen is a must.

3. The clamping force must be sufficient to prevent even slight parting of the mold halves because of the opposing force exerted by blowing pressures. Good mold closure is necessary to obtain uniform wall thickness at the parting lines.

4. A positive, dependable method of cutting, pulling, or pinching off the blown bottles is required to prevent interruptions in the cycle, and insure uniform "drawdown" for each bottle.

Coming Next Month

For Extrusion Plant Managers—simple rules of thumb for feedscrew selection.

Although the blow molding equipment evaluated here was an experimental unit, it was possible to blow bottles on a production basis. More than 2400 bottles were blow molded during one eight hour run without a single discard after the initial lineout. Improvements in design and the refinement of techniques should result in injection blow molding methods which will give the injection molder an economic advantage in bidding on small to medium size lot orders.

—■—

Our authors like to hear from readers. Send your questions and comments to Editor, SPE Journal, 65 Prospect St., Stamford, Conn. We will forward them to the authors.

The Cook-In Pouch — New Application for Plastics Films

Fred B. Shaw, *Continental Can Co., Inc.*

The cook-in pouch is a flexible package suitable for containing a quantity of prepared food in such a manner that it may be stored without significant loss of flavor, color or texture, and which may be heated to serving temperature without opening. When it reaches a suitable temperature, the pouch may be opened and the contents consumed without any other cooking process nor the addition of any other ingredients.

The Materials

Paper-Polyethylene Extrusion Laminates—This material has shown small degree of success, but this type of structure is a poor gas barrier and cannot withstand severe handling conditions; also cannot be used with a wide variety of prepared foods. **Aluminum-Foil Polyethylene Laminates**—have demonstrated range of usefulness which can be increased by adding a paper layer to the laminate construction. **Polyester-Polyethylene Laminates**—Most promising for Cook-In Pouch applications. Delamination of this combination was a problem originally, and stemmed primarily from the fact that initial room-temperature bonds were only in the range of 30 to 40 grams per inch of width (in the case of low density —.92—polyethylene) and even lower in the case of the medium density—.935—polyethylenes which are required in Cook-In Pouch structures to assure an adequately high softening point under all conditions.

The introduction of organic titanate primers (or bond promoters), which are applied to the polyester surface immediately prior to extruding the polyethylene thereon, resulted in great improvement in initial bonds, yielding values in the range of 150 to 600 grams/inch of width. However, is was repeatedly demonstrated that even this, due primarily to the variability, was not sufficient to be completely reliable in Cook-In service. Furthermore, the later, curing-type primers offered by some adhesive manufacturers, in spite of their initial 250 to 600 grams/inch bonds, were also judged to be inadequate since a high frequency of in-service delamination was experienced; once again it was believed that this was due to the variability of bonds obtained. These curing-type primers also have the additional disadvantage of being applied from toluol containing solvent systems which may not always be completely evaporated prior to the extrusion operation, when the primer is applied in-line. In such cases, any trace of trapped toluol will ultimately diffuse through the polyethylene and contribute an offensive odor and/or taste to the food contained within the pouch.

In the case of adhesive laminated Mylar®-polyethylene structures, bond strength values vary considerably, depending on the type of adhesive used. While some thermoplastic adhesives based on neoprene or Hycar-phenolic resin blends give fairly high and uniform bonds, these adhesives have too high an odor level to be acceptable for food containing pouches. Even should an odor-free thermoplastic adhesive for joining the polyester film to polyethylene become available, it is highly doubtful that such a material could be used effectively in producing such pouches since, by their very nature, they become soft and relatively weak adherents at the temperature of boiling water, where they must demonstrate their effectiveness.

Thermosetting adhesives, which were more recently developed, and which are typically of the polyester type, provide markedly superior bonds, ranging from 600 grams/inch to values greater than 1700 grams/inch bond—both of which are in excess of the internal strength of one or both of the two films and lead to termination of the test through tearing of either the polyethylene or Mylar®. These bonds are even further enhanced in heat seal areas due both to the temperature-pressure effect and the reinforcement of the polyester component of the laminate, so that heat seal strengths in excess of 4000 grams/inch are typical and 6000 grams/inch common. Such heat seal values are, of course, diminished at the temperature of boiling water; measurements at 212°F. indicating strengths of 900 to 1300 grams/inch—which are still ample to provide the performance required.

Checklist for film or laminates used in construction of Cook-In Pouch.

1. Non-toxic (FDA approved)
2. Heat softening point in excess of 212°F.
3. Heat sealable (at least one side).
4. Resist pinholing and stress-corrosion cracking.
5. Be sufficiently rigid to facilitate heat sealing of the mouth after filling.
6. Exhibit low moisture sensitivity.
7. Resist penetration by greases, oil and flavor components.
8. Have a low oxygen transmission rate.
9. Not impart any taste or odor to the food product.
10. Not embrittle or otherwise become physically unsuitable at —20°F.

Polypropylene shows some promise as the heat sealing component of a laminate; however an examination of this film's physical properties, principally its oxygen transmission rate of approximately 200 cc/100 sq. in./24 hrs./1 atm/25°C; its WVTR of 0.7 grams/100 sq. in./24 hrs.; and its softening point in the vicinity of 280°F. suggests that it might also serve as a single film pouch material in the fabrication of Cook-In pouches for many vegetables. To date, this promise remains unrealized because of the low impact strength of polypropylene film, coupled with the uncertain toxicity clearance of impact resistant blends of this polymer with elastomers.

Some Promising Laminate Candidates

Cellulose acetate-medium density polyethylene
Poly(Vinylidene Chloride)-medium density polyethylene
Polyamide-medium density polyethylene
Polyester-polypropylene film laminate
Polyester-vinyl chloracetate
Paper-aluminum foil-vinyl chloracetate

Prediction of Impact Resistance from Tensile Data

This article reports significant advances in an area where many have tried for 20 years—tensile tests determined at strain rates which correlate with impact resistance tests.

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During the course of an extensive research program on compounding and molding of plastic compositions the need developed for laboratory tests which would show significant trends in gain or loss of impact resistance even when applied to small quantities of experimental materials. Test methods like the different versions of Pendulum (4, 5, 10) and Falling Weight tests (1-3), whatever may be their merits as a quality index, do not measure separately the stress and strain dimensions of rupture energy, which is critical advisory information to the chemist's approach to design of plastic compositions. Tensile strain-curves should give this information in addition to providing a measure of the energy of rupture, which is here defined as the area under the complete stress-strain curve.

Unfortunately when tensile data were determined at commonly specified low rates of strain (11) the rupture energies calculated from the curves did not correlate with service experience on impact resistance of products made from any plastics so rated. Most failures of correlation occurred for the thermoplastic systems. Undoubtedly, this can be explained by Maxwell's observations (12) which we confirmed in many instances that the variation of tensile properties can be erratic when rates of straining are increased.

Obviously there is a need for tensile tests determined at strain rates which approximate the maximum existing under rough handling impact conditions. To satisfy such a need, several high speed machines have been developed (13, 15). Unfortunately, most of these specialized methods are either tedious, expensive, or require apparatus which is still a rarity in plastics development laboratories. At least until such time as when high speed tensile machines become more widely accepted, the question is appropriate as to whether improved results might be obtained using commonly available tensile machines to better advantage.

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This hope might be realized if the energy dissipation mechanism which prevails under impact conditions dominates also the tensile properties at strain rates which are possible at the higher speeds on more popular types of tensile machines. The practical advantages coming from realization of such a hope seemed sufficient to justify a program to compare a considerable variety of plastics under uniform conditions, both with respect to destructive falling weight tests on large spans of sheet as well as with tensile tests on small specimens.

Falling Weights Tests

When impact resistance specifications are written, most often a falling weight test is used. Despite the directness of the approach, such tests are not easy to define. In falling weight and other projectile impact tests numerous variables need to be considered regarding the geometry of the specimens and the relation of specimen shapes to geometry of the apparatus. Even the choice of the units for the quantity measured requires an arbitrary decision on what is to be considered the fraction of area or volume responding to impact forces. Because it is so difficult to find theoretical solutions for these problems, arbitrary standard conditions are defined in most instances. Here the test conditions were also somewhat arbitrary.

Two falling weight machines were used, one for the less tough and one for the more tough plastics. The first, which was used the least, was simple falling ball type, with weights up to five pounds from heights up to six feet. The second (18), because it dropped variable weights up to 64 pounds from a six foot height, was more hazardous to the operators and required more care to guide the impacting stress normal to the surface.

Table I lists the plastics tested. The code letters of the second column will be used to identify the particular plastics in the figures shown. This group contains three types of thermoplastics, namely, glassy-homogenous polymers, heterogenous blends including block polymers, and such as are commonly called crystalline polymers. Also, a median quality fiberglass reinforced polyester laminate was included to illustrate this group. The thermoplastics were sheet stock either calendered or compression molded, as indicated in *Table I*. For all measurements, samples were conditioned for at least two weeks and tested at 23 ± 1.1°C and 50 ± 2% relative humidity.

Large sheets of 2¼ sq. feet were used to minimize boundary effect. The edges were held by four pairs of parallel strips to minimize stress concentration at the supports. In using the large apparatus, varying weights applied to the same striking head were dropped from heights between three feet and six feet. The force striking a specimen was increased progressively on different parts of the same sheet until failure occurred. This value was not reported, but it located the starting range for other tests. Another specimen was inserted and testing was begun with the energy for the first blow just below that which caused failure of the previous specimen. The weight was increased until failure was observed. The procedure was repeated on new specimens until the minimum energy was found which would produce a fracture pattern in the specimen in the first blow. Values for energies for a single blow just sufficient to cause failure of two sheets, and energies just short of break of two more sheets were averaged. The average

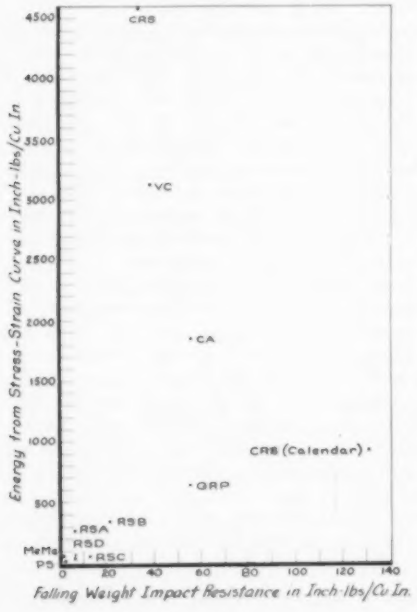

Figure 1. Falling weight energy compared to stress strain energy determined at 3.33 x 10^{-3} inches per second.

of these four values are reported as the rupture energy by falling weight test in *Table I*.

The results are reproducible to about ± 15% on the same stock of polymer if specimens with visually obvious voids, cracks or other gross defects are avoided. This method is very wasteful of material and effort, and is too costly and slow for convenient use in laboratories devoted primarily to compounding plastics. However, the conditions of the test

Table I. Identification of Plastic Sheet Stocks and Their Impact Resistance Ratings by Falling Weight Tests

Type Description	Code used in Figures	Modulus in 10^5 lb./in.^{2}	Estimate of Energy to Fracture 50% of Specimens in. lb./in.^{3}
Polymethylmethacrylate[a]	Me Me	5.12	0.74
Polystyrene[a]	PS	4.06	1.7
GRS Rubber-Polystyrene Blend A	RSA	2.54	6.9
GRS Rubber-Polystyrene Blend B[a]	RSB	2.97	21.
GRS Rubber-Polystyrene Blend C	RSC	2.86	13.
GRS Rubber-Polystyrene Blend D[b]	RSD	3.99	6.6
Terpolymer, Styrene, Butadiene, Acrylonitrile[a]	none	2.16	37.
Terpolymer, Styrene, Butadiene, Acrylonitrile[a]	Terp	2.20	45.
Glass Reinforced Polyester-Styrene Copolymer[a]	GRP	14.5	52.
Polyvinylchloride	VC	4.3	40.
Styrene Copolymer-Nitrile Rubber Blend[a]	none	3.48	33.
Styrene Copolymer-Nitrile Rubber Blend[a]	CRS	2.78	131.
Cellulose Acetate	CA	3.92	61.

NOTE: a, compression molded; b, extruded, all others calendered sheet. The secant modulus is slope of line drawn from origin to first maximum before stress relaxation in 20 in. per min. stress-strain curve, or to ultimate tensile strain when nearly linear curve lacks an obvious yield point.

are such that the results are consistent with qualitative observations of comparative service durability of these plastics in molded products. The polystyrene and polymethyl methacrylate are known to have poor impact resistance. The rubber-styrenes and some other polyphase blends, including crystallizable plastics, are known to be superior in this respect to the homogenous, glassy plastics. The glass reinforced polyester here included was in the middle of the range among impact resistant commercial plastics of both reinforced and non-reinforced types.

Correlation of Falling Weight Test with Tensile Data

Rupture energies from tensile curves determined at rates of 0.2 in. per min. or .00333 in. per sec. (A.S.T.M. D638-52T) do not correlate with falling weight impact resistance *Figure 1*. To determine whether this poor correlation persists at higher rates, stress-strain curves were determined with a modified Instron Tester also at rates 10 and 100 fold greater.

The stress-strain curves were determined with a modified Instron Tester on ASTM Type 1 tensile specimens prepared from same stock as was used in the impact tests. The standard machine is capable of measuring stress-strain curves at rates up to 0.333 in. per sec. if the load cell of the Instron Tester, which consists of wire strain gages bonded to steel beams, is connected as two legs of a Wheatstone

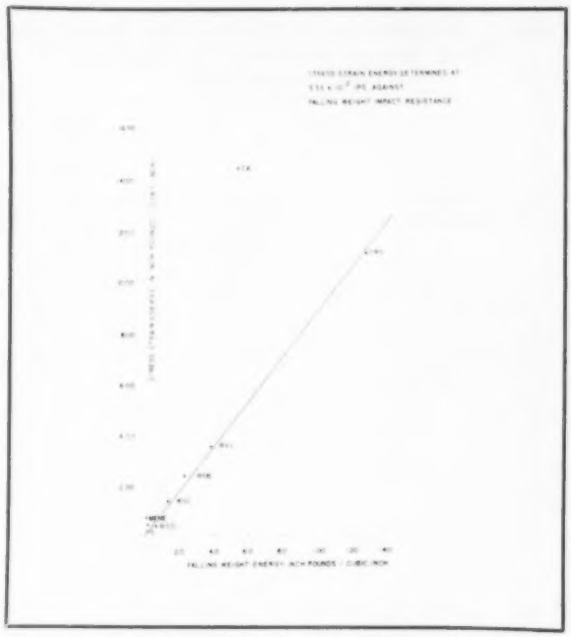

Figure 2. Falling weight energy compared to stress strain energy determined at 3.33 x 10^{-2} inches per second.

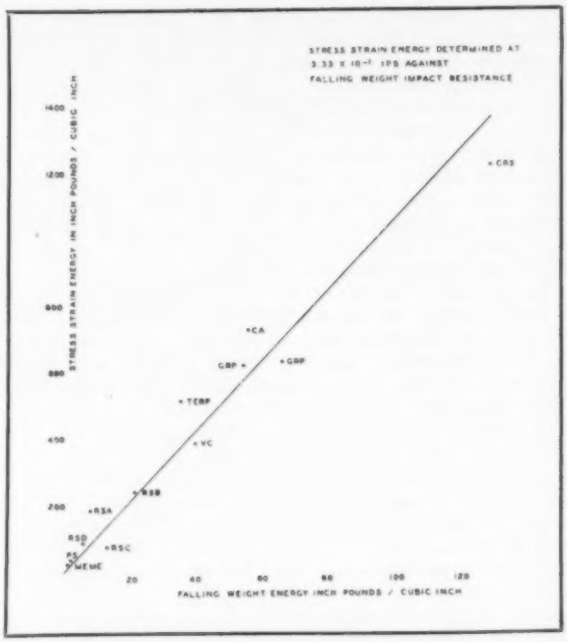

Figure 3. Falling weight energy compared to stress strain energy determined at 0.333 inches per second.

bridge to a Sanborn four channel recorder Model 150-200B/400, calibrated for the load cell. The constant rates of jaw separation on this machine are quite precise; hence a stress-strain curve can be constructed using the Sanborn stress-time curve and the time-extension factor provided by the machine setting.

Unfortunately, the strain determined by such a method is an approximation because elongation, in such a setup, is not a direct function of time. This may be due to specimen geometry, specimen anisotrophy, or machine strain. This problem was studied extensively, using a variety of other expedients like strain gages over sections of the specimens. All other methods lacked reproducibility from specimen to specimen. Estimating strain from the jaw separation seemed to give integral values which provided more consistent estimates of strain than did strain gages on the specimen.

Ordinary strain, $(L - L_o)/L_o$ was used rather than the true strain $\log_e L/L_o$ because, even at strains of 30%, the error introduced was less than 4%. Because of the small error involved, stress was expressed as lb. per sq. in. of original cross section rather than as lb. per sq. in. of cross section at break. Areas were calculated by counting squares on the record charts and multiplying by the proper factor.

Table II reports average values of six to ten measurements of tensile strength and elongation at each of three speeds. The standard deviations are less than ± 10 of the reported values.

It can be seen that, while the tensile strengths show the comparatively moderate rise shown in *Table II* (with crystalline polymers showing more than do amorphous), the ultimate elongation decreases considerably as rate is increased for nylon 6, rigid vinyl chloride, cellulose acetate and acrylonitrile-styrene-rubber blends. In general, data for glass reinforced thermoplastics were less rate sensitive, as is shown for the typical sample.

The area under the stress-strain curve was reported as rupture energy, W, in in. lb. per cubic in. For lack of a theoretical correlation equation, the empirical expedient was resorted to of plotting falling weight energy per unit volume against tensile rupture energy per unit volume *(Figures 2 and 3)*. This provided correlation factors of practical utility but of indeterminate theoretical significance.

Figure 2 for rates of 0.033 in. per sec. shows a correlation which deviates less from linearity than in *Figure 1*. At 0.333 in. per sec. *(Figure 3)* the linear correlation is even better, even cellulose acetate falls into place. The *Figure 4* curve can be described by the equation $W = 10\,F$, where W is the tensile energy, F the falling weight energy.

The existence of a correlation between tensile and falling weight energy absorption is not an obvious conclusion. In a tensile test, the forces are mainly uniaxial, and speed of strain is constant. In a falling weight test, the stress distribution is complex, and the strain rate varies from zero to a maximum in a pattern which cannot be calculated easily from theory and which is extremely difficult to determine experimentally.

Although this correlation is far from perfect, it is surprisingly good in view of the inherent uncertainties of both test methods.

A Method of Approximating Tensile Energy At Impact Rates

The foregoing results suggest that tensile curves determined at speeds far short of impact strain rates provide a quantitative prediction of falling weight impact resistance which in most instances is accurate to better than 20%. This was somewhat unexpected and some doubts persisted that the apparent agreement of the rating scales by the tensile and falling weight tests might be a fortuitous coincidence only for the 0.333 in. per sec. speed of tensile test. Obtaining data for complete curves over a wider range of higher speeds is difficult. Much work is being done in this field which tells us something of what the higher speed curves should be like. In particular, Beuche (23) and Strella and

Gilman (15) have shown that ultimate tensile strength tends to increase moderately at faster rates for most plastics, and usually less than 30% over the time scale of interest here. Elongation is more time sensitive. Hence, if it were known that ultimate elongations at 0.333 in. per sec. parallel values at much higher speeds, then considerable confidence could be placed in predictions from tensile data. This confidence would extend even to some of the newer methods (22) which are faster than ours but still fall short of ordinary impact speeds.

Our approach to checking the validity of the correlation of Figure 3 was to estimate the magnitude of stress-strain energies for several plastics at very high speeds by the following plan: (1) Elongation capacities were estimated at rates of strain equivalent to severe impact conditions. (2) Elongation values so obtained were combined with tensile strengths determined more precisely at lesser speeds so as to construct an idealized stress-strain curve along the lines of some plausible assumptions. From these idealized curves energy values were calculated. (3) These values were compared with falling weight impact data to determine whether correlation was still linear as was the case with 0.333 in. per sec. tensile data. The appearance of a comparable linear correlation would lend considerable empirical justification for use of the more precise tensile data at lesser speeds for predicting impact behavior.

Estimating Elongation at Impact Speeds

A method for estimating high speed elongation was suggested by some observations made using an unnotched Izod test. When struck near the end, specimens of the same plastic but of different thicknesses either fractured or bent without breaking so as to allow the striker to pass through. While the bending capacity of the thicker beams of brittle materials was exceeded at lesser impact energies than for thinner beams, ductile materials showed the expected converse behaviors. This suggested that when other conditions were nearly constant, finding the thickness at which ductile cantilever beams fractured could provide some measure related to the elongation capacity at impact rates. An equivalent procedure would be to vary the length of beams of constant thickness because shortening the beam has an effect similar to thickening it. The relationship (24) between outer fiber elongation, beam lengths, and thickness is given for elastic solids as:

$$e = \int_{x_1}^{x_2} \frac{d}{2} \cdot \frac{f\,x\,dx}{EI} \qquad (1)$$

where e is the elongation of the "outer fibers" between x_1 and x_2, f the force, d the thickness, and E and I the tensile modulus and moment of inertia.

If an elastic cantilever beam is struck at the end by a falling weight which projects over the edge of the beam a distance m, the beam will behave as did the specimens in the Izod test; either it will fracture or allow the weight to pass through after shortening its horizontal projection by the distance, m. In that event

$$m = \frac{1}{2}\int_0^x \left(\frac{dy}{dx}\right)^2 dx \qquad (2)$$

For a cantilever beam of negligible mass, compared to the striker, when loaded at the end the vertical deflection, y, is

$$y = \frac{1}{6}\,\frac{f}{EI}\,(x^3 - 3L^2x + 2L^3) \qquad (3)$$

where L is the beam length.

Solution of these two equations by differentiating (3), squaring the differential, substituting this value into (2) and integrating between zero and L gives a value for the impacting force

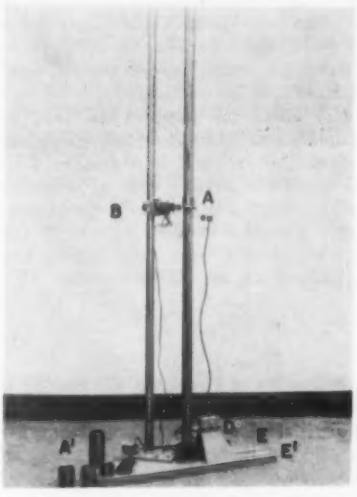

Figure 4. Cantilever impact tester.

$$f = \sqrt{\frac{15m.EI}{L^{5/2}}} \qquad (4)$$

This makes it possible to obtain a value of the integrated elongation by substituting equation (4) into (1)

$$e = \frac{d\sqrt{15m}}{2L^{5/2}} \int_{x_1}^{x_2} x\,dx \qquad (5)$$

This equation shows that the elongation would be greatest immediately adjacent to the support of the beam. If a strain gage is used to define the limits in equation (5), by attaching one of gage length, j, to the beam with one gage mark near the support. Then

$$\epsilon = \frac{e}{j} = \int_{L-j}^{L} \frac{d\sqrt{15\,m}}{2L^{5/2}\cdot\,j}\,x\,dx \qquad (6)$$

$$\epsilon = \frac{d\sqrt{15m}}{4L^{5/2}}\,[\,2L - j\,] \qquad (7)$$

A tester which could impart an impact stress at the end of cantilever beams of varying lengths and thicknesses was constructed. It is shown in *Figures 4 and 5*. Here the falling weight, A, was varied by adding the rings, A', ranging from eight ounces to 20 pounds. The solenoid, B, which released the weight, could be adjusted so that the weight could be dropped from any height up to six feet. This provided speeds up to 235 inches per second. The sample was clamped in support, D. The length of the beam, L, was determined by the amount of sample projecting from the clamp, D. The clamp was moved forward by sliding in grooves, EE', until the tip of the beam touched the edge of hemisphere, h, riveted to the bottom of the striker, A (shown in *Figure 5.*). The shortest distance from the outer circumference of the hemisphere to the outer circumference of the striker is the amount the projection of the beam must shorten, m. The clamp was then made immovable by tightening set screws.

To test equation 7, an A-3 strain gage of 13/16 in. length was cemented near that end of a plastic cantilever beam which was inserted in the clamp of the tester. The strain was measured by connecting the gage through a direct current Wheatstone bridge and amplifier to an oscilloscope whose output was photographed by a Polaroid Land camera. For 11 samples tested, the recorded strain averaged 12% less than what was calculated from equation 7. Whether

this was due to errors in the construction or operation of the machine, or to the viscoelastic behavior of plastics was not determined. In any event, the accuracy was comparable to that of other methods of strain measurements, and seemed sufficient for the purpose here intended.

As would be expected, all of the samples fractured at the jaw. Hence, the ultimate strain of interest should occur in the narrow region near the jaw which is smaller than could be spanned with available strain gages. If equation (7) is valid, it is possible to assume a strain gage of negligibly short gage length placed immediately next to the jaw. Then j drops out if equation (7) and the strain ϵ can be calculated knowing only d, m, and L by equation (8).

$$\epsilon = \frac{d\sqrt{15m}}{2L^{3/2}} \tag{8}$$

The theoretical approximation of equations (7) or (8) is valid only for linear elastic solids. In plastic deformation, a hinge should develop adjacent to the support making the strain in the hinge higher than that calculated by equation (8), hence this equation can expect to hold only to the extent to which plastics approximate linear elastic behavior at high speeds or strain. The strain gage measurements suggest that deviation from behavior expected of elastic solids is small.

The ultimate elongation in cantilever bending of a series of plastics was calculated after determining critical beam length, L, as follows: The minimum extension was found where six beams failed to fracture when struck on one end with the falling weight. The length was then shortened in steps. Six beams were tried at each successive length, until an extension was reached where all of them broke. Beam length was then plotted against number fractured. The length at which 50% of the beams fractures as interpolated from the curve was the value used for L in equation (8). Some results of the elongation test are shown in the last two columns of *Table II*.

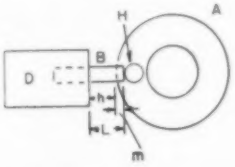

Figure 5. Diagram of striker of cantilever impact tester.

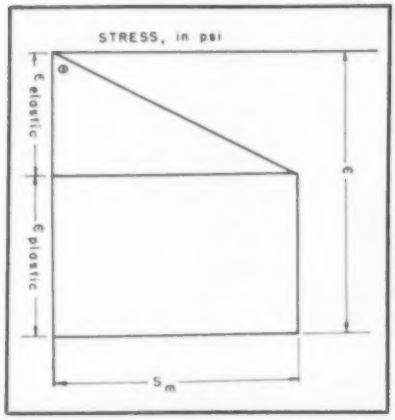

Figure 6. An idealized stress strain curve.

Rupture Energy Estimates from Idealized Stress-Strain Curves

Figure 6 shows an idealized stress-strain curve for ductile plastics. The area of the triangular section represents the elastic energy and that of the rectangular section the plastic flow contribution. The ordinate is divided between the elongation which took place elastically and that which was plastic. The former is

$$\epsilon_e = \frac{S_m}{E} \tag{9}$$

The elastic energy is

$$W_e = \frac{S_m \epsilon_e}{2} \tag{10}$$

The plastic energy is the area of the rectangle

$$W_p = S_m \epsilon_p = S_m (\epsilon - \epsilon_e) \tag{11}$$

where ϵ is the ultimate elongation. The total energy is

$$W = S_m \left(\epsilon_p + \frac{\epsilon_e}{2}\right) = S_m \left(\epsilon - \frac{\epsilon_e}{2}\right) = S_m \left(\epsilon - \frac{S_m}{2E}\right) \tag{12}$$

Using measured values for strength, elongation, and tensile modulus, equation (12) gives an approximation of a high speed stress-strain energy. The validity of this approximation is limited, of course, by the numerous assumptions made, particularly that values of S_m and E taken from data at 0.333 in. per sec. can be combined with ϵ estimated in the range of 166-235 in. per sec., and that high and slower speed curves differ mainly in the ductile portion. *Figure 7* shows the correlation or rupture energies from such hypothetical stress-strain curve (called cantilever impact energies) versus the falling weight impact energies at failure.

The relation is linear, as it was also for the 0.333 in. per sec. tensile data, but the ratio W/F is 14 instead of 10. This mainly reflects the observation that elongations obtained by equation (8) tend to be greater than from tensile tests. Considering the precision of the data, it seemed reasonable to conclude that energies required to cause fracture in this particular falling weight test are 10 to 20% of the energy of rupture deduced from high speed tensile curves. While this is precise enough to guide compounding studies, obviously something better would be desirable for engineering structural design of plastics.

Only three plastics deviate more than 16% from the curve as it is drawn. The main exceptions are the brittle plastics polystyrene poly(methyl methacrylate), and rigid vinyl chloride, all of which tend to fail by shattering rather than tearing. Possibly the test has no quantitative significance for brittle materials. More probably, the polystyrene and poly(methyl methacrylate) cantilever beams should not have been compared in this correlation because precisely dimensioned cantilever beams could not be machined from the sheet stock and hence such were prepared by injection molding. The falling weight tests were performed on compression molded sheet from the same molding compound. Injection molded samples, in general, tend to have better tensile properties than do compression molded samples which is the direction of the deviation shown from the correlation curve in *Figure 7*. For poly(vinyl chloride) the deviation might have been expected because its stress-strain curves *Figure 11* are unusual and if the same curve pattern prevails at high rates, such would be represented poorly by the idealized curve of *Figure 6*. In any event, only poly(vinyl chloride) was misranked so badly as to mislead seriously if its impact resistance were predicted by equation (12).

Since this cantilever bending test is easily performed, it can be used in cases of doubt to confirm predictions of more precise energy values from slower speed tensile data. However, exceptions like poly(vinyl chloride) certainly must be anticipated as a possibility, and such exceptions do occur among the ductile, rigid thermoplastics. Fortunately, examination of variable speed tensile data provides a very considerable qualitative indication of such non-typical behavior.

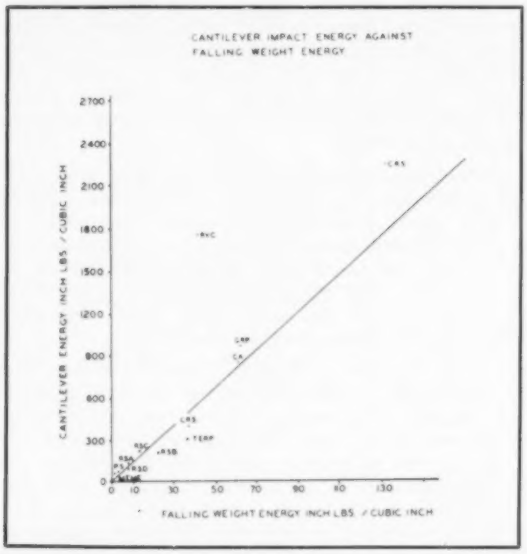

Figure 7. Cantilever impact energy compared to falling weight energy.

Typical Stress-Strain Curves

If one classifies plastics as to whether or not they are impact resistant, then the inferior category is occupied mainly by plastics with a "brittle" type of stress-strain curve. Such a curve is illustrated in Figure 8 for methyl methacrylate. This is almost linear with ultimate strength around 6,000 psi. This type of curve shows very little variation in shape between rates of 3.33×10^{-3} and 3.33×10^{-1} in. per sec.; only the slope and height change in a small way. In general, this type of material shows energy values of less than 50 and 500 in. lb. per cu. in. respectively by the falling weight and tensile tests, and notch sensitivity is so considerable as to make it difficult to get duplicate re-

Figure 8. Stress strain curves for polymethyl methacrylate.

Table II. Tensile Strength S (in Thousands of psi), Percent Elongation at Variable Strain Rates in inches per second

Material	Rates	0.00333		0.0333		0.333		166	235
		S	e	S	e	S	e	e_1*	e_2*
Glassy types									
Polystyrene		4.4	1.4	5.3	1.6	5.5	1.5	1.9	1.9
Poly(methyl methacrylate)		6.1	1.9	7.2	2.0	6.9	1.4	1.6	1.6
Crystalline types									
Poly(vinyl chloride)		7.7	48	7.1	7.2	10	7.0	38	18
Cellulose acetate		4.6	26	6.5	26	7.2	22	15	13
Nylon 6		5.9	87	7.8	59	9.0	19	—	—
Polypropylene		4.6	119	—	—	5.4	21	12	—
Polyphase amorphous blends									
Rubber-polystyrene A		2.8	12	3.1	13	3.4	7.9	4.4	—
Rubber-Polystyrene B		2.9	5.6	3.3	7.6	4.0	8.8	5.7	—
Rubber-polystyrene C		3.2	10	3.8	8.2	4.2	4.5	5.9	7.8
Rubber-polystyrene D		1.7	3.7	2.7	2.1	3.3	2.4	4.0	2.5
Terpolymer		3.6	11	3.8	4.4	4.0	12	—	9.3
Styrene copolymer—with Nitrile rubber (calendered)		2.8	44	3.8	40	3.8	35	59	56
Styrene copolymer—with Nitrile rubber (compression molded)		—	—	—	—	3.7	8	—	10
Fiberglass reinforcement									
Glass reinforced polyester		38	5	—	—	39	3.7	—	4.1

* These values of e are calculated from certain assumption applied to the cantilever bending test described in text.

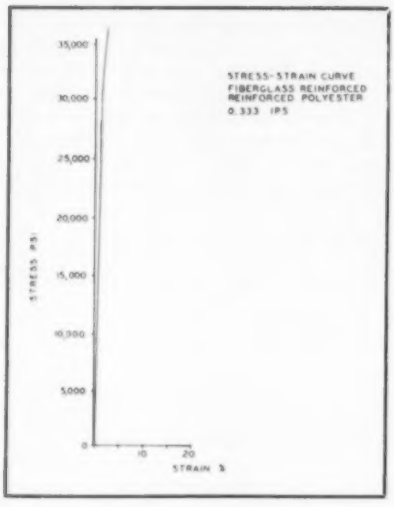

Figure 9. 0.333 IPS stress strain curve for fiberglass reinforced polyester.

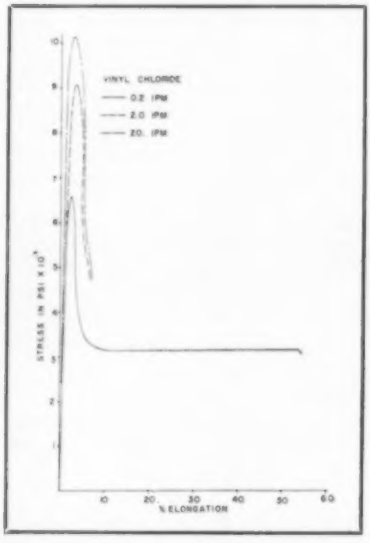

Figure 10. Stress strain curves for polyvinyl chloride.

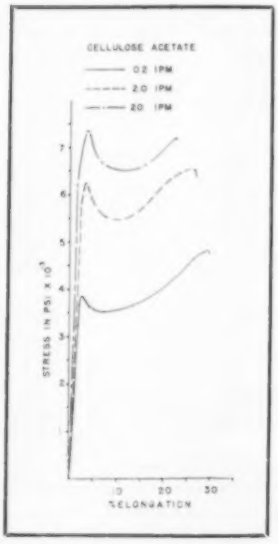

Figure 11. Stress strain curves for cellulose acetate.

sults. Plastics having tensile energy ratings which exceed 500 in. lb. per cu. in. seem to be rated as impact resistant in current industrial usage.

Comparison of Figure 9 with Figures 10-14 suggests that there are two types of curves at 0.333 in. per sec. which give high enegry: Type I, strong plastics where area under the curve is high because tensile strength is high, and Type II, ductile plastics, which have markedly lower tensile strengths but high energy values because of high elongation. Class I among impact resistant structural plastics is occupied now mainly by the glass reinforced thermosetting laminates *(Figure 9)*. These have a nearly linear curve with a slight yield at the top. These materials escape classification as brittle plastics only if their tensile strengths exceed about 40,000 psi.

While tensile tests at constant rates of 0.0033 in. per sec. give a tensile curve for rigid poly(vinyl chloride) *(Figure 10)* which would place it in the ductile class with very high energy absorption, the 0.33 in. per sec. curve and the falling weight test places it in the same category as the median quality class reinforced polyesters. The stress-strain curve beyond the yield point bends downward steeply, with very little gain in elongation.

The other high energy absorbing plastics described here show considerable ductile flow beyond the yield stress at speeds equal to or exceeding 0.333 in. per sec. Although these plastics fall into three very different chemical classifications, blended polyphase plastics, block polymers, and crystalline plastics, their stress-strain curves are quite similar. The curves of all three types were alike *(Figures 12-14)* and can be considered as varients in shape and dimensions of that shown for cellulose acetate *(Figure 11)*. The general pattern of *Figure 11* can be regarded as typical for Class II Structural thermoplastics of high impact resistance.

In most of our experiments where properties of a base polymer were modified by chemical changes and, or, addition of plasticizers or other constituents, examination of the general character of the 0.333 in. per sec. curves provided immediate qualitative information regarding whether the change of composition under consideration had advanced or retrogressed from the objective of upgrading impact resistance. Computation of rupture energies gave a quantitative ranking of comparisons. In cases of doubt, the magnitude of the ultimate elongation was checked with the cantilever bending test which disclosed whether or not high elongation was preserved at high rates of strain. The practice here described proved to be an efficient guide to an extensive program of experimentation where alternatively either thermoplastic or thermosetting resins were used in many variations to get impact resistant molded products.

In the course of such studies the puzzling question was raised as to why thermoplastics, which are dissimilar in chemical constitution, nevertheless all showed stress-strain curves of the Class II type when finally compounded into plastics which were impact resistant. Possibly some common condition of structure has yet to be defined precisely which is more important in determining this sort of tensile behavior than are apparently great differences in the usually assigned molecular models.

It should be noted that when speed of tensile testing is increased, the greater should be the deviation from isothermal conditions and the better should be the approximation obtained of an adiabatic tensile test. Possibly speeding the tensile test up to certain limits provides mainly an indirect measure of the heat generated and the effect of heat on the strength determining structural factors. Consideration of the implications of such an assumption to the design of plastics is a separate study beyond the scope of this paper.

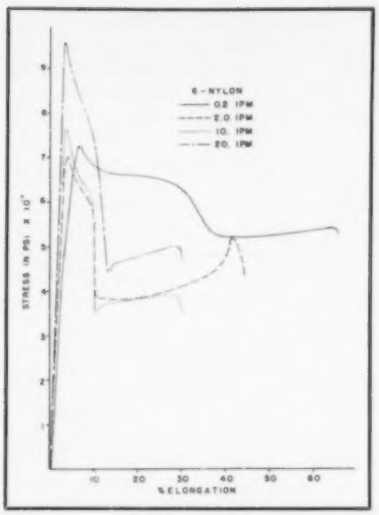

Figure 12. Stress strain curves for 6-nylon.

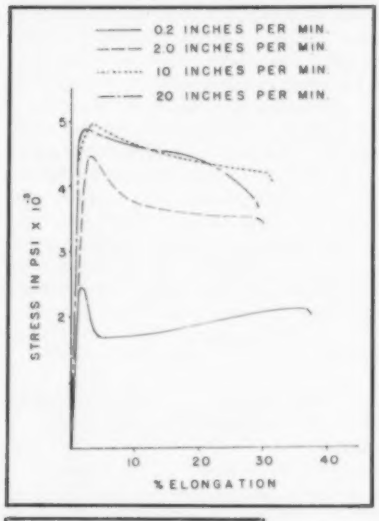

Figure 13. Stress strain curves for copolymer styrene-nitrile rubber.

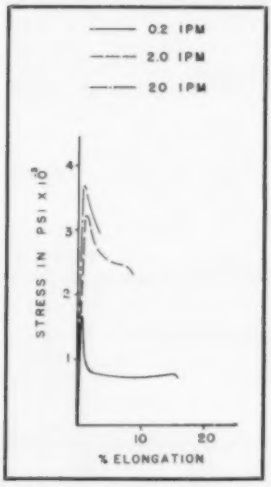

Figure 14. 0.333 IPS stress strain curve for Rubber Styrene C.

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NOTE: This paper abstracts and updates a part of the experimental work reported by Robert M. Evans in a Ph.D. Thesis on "Microstructure and Mechanical Behavior of Impact Resistant Thermoplastics," Case Institute of Technology, 1958. The author would be pleased to reply to particular inquiries for greater detail on technique or data which are cited in summary form in this paper.

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Our authors like to hear from readers. Send your comments and questions to Editor, SPE Journal, 65 Prospect St., Stamford. We will forward them to the authors.

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Painting Versus Molding In Color

Where small quantities of materials and special colors are involved, it may be cheaper to paint, rather than mold in color.

The rapid growth of the plastics industry within the past decade and the increased types of new plastics, with a multitude of applications, has presented a constant demand upon coating suppliers for new and improved products. These requests for new coatings are encouraged either by the desire to make a product more eye-appealing or to lower the manufacturing costs of the item.

One of the most significant developments is just now in its infancy. This idea revolves about and is hinged upon both product appearance and the need for cost reductions. The thought is to paint thermoplastic items molded in neutral-colored or reprocessed plastic rather than molding in the desired color. The idea itself is not a new one. It is one which has been thought about by a good number of people over the last few years. To some extent it has been done in the past, notably on TV masks, but the full advantages of painting have only lately been recognized.

Coming Next Month

Clarification of an urgent question confronting plastics films makers: Does the film comply with the new Food Additives Amendment to the FDA?

Quality of Thermoplastic Paints

With the advent of the patented butyrate-acrylic paint systems for use on polystyrene, and in particular with the refinement of these systems has come the answer to the functional part of the problem. These paints will meet with quality demands for adhesion, hardness, mar resistance, gloss, color and light stability, and economy of application.

The economy of such spray coatings regarding the cost of the paint itself and the application of the coating, is quite important. Although mileage of a particular paint will vary with film thickness, design of the part, and application techniques, a normal mileage of 250 square feet per gallon will be assumed in later calculations. This is low, since most of these paints will afford 300 square feet per gallon, and in some colors, particularly Bronzeless Golds, 325 square feet per gallon. These are actual working figures and are not mere theoretical values. The coating is fast drying—touch dry in 2 to 4 minutes and pack dry within 30 to 45 minutes, definite operating advantages. Faster drying speeds can be obtained if heat lamps or ovens are used. In addition to having excellent adhesion to both general-purpose and high impact polystyrene, the same coating may also be used on acrylic, acrylonitrile, rigid vinyl, cellulose nitrate, cellulose propionate and ethyl cellulose. It can be easily removed from general-purpose and high impact polystyrene without damage to the plastic. It has excellent adhesion to treated metals and may be applied directly as an air dry material, with no primer, over properly treated surfaces. It may also be used as a baking material over treated or untreated metals. The thoroughly dried pigmented paint will have 3-H pencil hardness and for some colors a pencil hardness of 4-H will be obtained.

Tabor Abraser tests were conducted using CS-10 Calibrase wheels with a 500 gram load to give a comparison in abrasion resistance between the butyrate-acrylic clear lacquer and a clear lacquer which is reported to be the acrylic type currently in use for painting automobile bodies. The results of this test disclosed an average requirement of 1850 cycles per mil of film abrasion for the automotive acrylic lacquer, whereas the requirement for the butyrate-acrylic coating was 2425 cycles per mil of film abrasion. Since the addition of pigments to clear vehicles will change abrasion resistance, a pigmented metallic color was tested in the butyrate-acrylic system and compared to the same color in the acrylic system. The results of this test showed the butyrate-acrylic formation to be slightly more resistant than the automotive lacquer. An important point: The butyrate-acrylic paint was loaded seven times higher with pigment and aluminum than was the automotive lecquer and hence provides greater hiding power.

Additional Tabor Abraser tests were made to compare the abrasion resistance of general-purpose polystyrene to the butyrate-acrylic paint. Since the paint was heavily pigmented with titanium dioxide, a heavy white pigment, it was necessary to utilize the standard Volume Loss Method of the Wear Index test, prescribed by the manufacturers of the Tabor Abraser, to compare the paint to clear molded general-purpose polystyrene. The test parts were subjected to 500 cycles on the Abraser equipped with CS-10 Calibrase wheels under a 250 gram load. The test results are as follows:

$$\frac{10.6 \text{ mg} \times 1000 \text{ cycles}}{1.87 \text{ sp. gr.} \times 500 \text{ cycles}} = 11.34$$ Wear Index (Volume Loss Method) of white butyrate-acrylic paint.

$$\frac{12.0 \text{ mg} \times 1000 \text{ cycles}}{1.05 \text{ sp. gr.} \times 500 \text{ cycles}} = 22.86$$ Wear Index (Volume Loss Method) of general-purpose polystyrene.

Comparison $\frac{22.86}{11.34} = 2.02$

Or, the painted part has twice the abrasion resistance of general-purpose polystyrene.

Economics of Painting Vs. Molding in Color

Turning to the economical side of the problem, only a cursory glance at *Table II*, showing the prices charged for color matched polystyrene molding powder in quantities of 5,000 pounds or less, indicates a raw materials price savings

can be enjoyed by purchasing neutral or reprocessed stock, as standard materials, and painting to achieve color rather than molding in specific colors. As is shown on *Table II*, the raw material cost of neutral styrene vs. color matched styrene in a quantity of 4,250 pounds shows a difference of 13¢ per pound in favor of using neutral stock. As the quantity demand *decreases* the advantage becomes more and more in favor of painting neutral stock. *The plastic raw materials* price advantage varies from 18¢ to 78¢ per pound using reprocessed styrene and will show the biggest price savings when reprocessed multi-color is molded since almost 14½¢ per pound is saved at 8,500 pound level and about 84¢ per pound at the 850 pound level. The *raw material* price savings is the key to the economics of painting instead of molding in special color. The actual *net savings per piece part* is also determined by the cost of the paint and the paint application costs, as will be shown later.

Table II lists the pounds of styrene molding powder not in normal price increments, but rather at intermediate points between normal increments. This was done to facilitate paint costs comparisons while still keeping the chart valid. Since, oddly enough, the quantity price breaks for paints fall at these intermediate points. Crystal styrene is not listed since excessive amounts of some colors of paints would be required to provide an opaque film.

Table II was constructed using prices prevailing for polystyrene at the time of this writing. It is not important that the price for styrene remains constant for any length of time. The table will continue to be valid as long as the differential, at a given level, remains the same between special-color styrene and neutral or reprocessed styrene. The prices may fluctuate up or down but if the differential is constant the table is believed valid. Should the differential vary, as it may with reprocessed styrene, the method of calculation is simple enough for anyone to adjust the table accordingly.

Attention is called to *Table I* which contains the basic calculations and assumptions made to arrive at the figures on *Table II*. The significant figure is the paint mileage expressed in equivalent pounds of polystyrene. This shows that one gallon of paint will cover the paintable area afforded when 170 pounds of styrene are molded. We shall use the reciprocal, .0059 gallons, in many of our calculations. Although the wall thickness of a specific part generally may vary from .06″ to .125″ those parts most likely to require special colors were found to average .125″ (⅛″), hence this figure was used in preparing Charts I and II which are shown for illustration and guide purposes. Of equal interest, and still valid, would be similar charts based upon thinner molding to show savings—greater or smaller than those based upon ⅛″—depending upon the number of parts to be molded and the paint costs. Since the method of calculation is simple these chart extensions are urged. The term "paintable area" is defined as that surface area which is designed to have aesthetic value or appeal when examined. As such it usually means the outside area; hence not included is the interior of the molding and the supporting ribs. These figures, in *Table I*, taken as an average, may vary from one case to another; however, simple calculation will adjust them as may be required for more exact measurement.

The paint prices shown on *Table II* are average prices

Table II. Tabulation of Costs to Paint Virgin White, Color or Reprocessed General Purpose Polystyrene Versus Molding in Special Color

Pounds of Polystyrene	34,000	17,000	8,500	4,250	2,550	1,700	850
Price (dollars per pound)[1]							
Virgin Matched Colors	$0.255	$0.27	$0.30	$0.40	$0.50	$0.60	$1.00
Virgin White	$0.255	$0.26	$0.26	$0.27	$0.27	$0.27	$0.27
Reprocessed Colors	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
Reprocessed Multicolor	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155
Gallons of Paint Required[2]	200	100	50	25	15	10	5
Cost of Paint per Gallon[3]	$7.50	$7.70	$8.00	$10.00	$11.40	$13.40	$16.40
Cost of Paint per Pound of Styrene	$0.044	$0.045	$0.047	$0.059	$0.067	$0.079	$0.097
Cost of Paint plus Application[4]	$0.094	$0.095	$0.097	$0.109	$0.117	$0.129	$0.147
Savings per Pound by Painting vs. Molding in Color[5]							
Virgin White	−$0.094	−$0.085	−$0.057	+$0.021	+$0.113	+$0.201	+$0.583
Reprocessed Colors	−$0.059	−$0.045	−$0.017	+$0.071	+$0.163	+$0.251	+$0.633
Reprocessed Multicolor	+$0.006	+$0.020	+$0.048	+$0.136	+$0.228	+$0.316	+$0.698

[1] Based on prevailing price on 1/30/59.
[2] 0.0059 × lbs. of polystyrene—see Table I.
[3] Average cost per gallon including cost of necessary thinner.
[4] Application cost including overhead, labor, etc. average at 5¢/lb. of polystyrene coated.
[5] Virgin matched color price minus price of other material plus cost of paint and its application. Plus signs indicate savings in dollars per pound by painting.

for specially color-matched paint, and as such are more expensive than standard colors. The cost of the necessary thinner, one gallon of thinner per gallon of paint, has been included in the paint cost and has been averaged at $1.50 per gallon.

By necessity the table can not include exact costs for applying the paint since these costs will vary somewhat from one molding shop to another and, within one shop, from part to part. However, several large molders, experienced in both molding and painting have agreed, excluding the cost of paint, that the labor, overhead and other costs of applying paint on parts is approximately 5¢ per pound of molded plastic. Their figures are based upon painting an entire part, and as such this cost is less, on a square foot basis, than painting masked or restricted portions of a part as is common when decorating with multiple colors. *Table II* shows the cost of paint plus application costs. This is calculated by adding 5¢ to the cost of paint per pound of styrene.

The above calculations allow us to predict the total savings per pound when neutral or reprocessed styrene is painted rather than by achieving the color by molding with special color plastic. These predicted savings are shown on *Table II* on a per pound basis. By relating pounds to the number of items molded per pound, the savings per part are easily found.

In addition to the savings per piece part often obtained by painting, significant additional considerations, which several molders have emphasized, should not be overlooked. Some molding departments are no doubt confronted with an increasing frequency of small runs. In the past there were fewer jobs calling for short runs; however, in today's competitive market more and more brand items are being molded in different sizes and shapes and in different colors as the sales advantages of doing so become more apparent Obviously painting will not solve the mold changing problem, but it can solve the loss resulting from color changes. This loss includes machine down time, purging costs and material wasteage through rejects encountered when starting a press. These costs are not included in the calculations.

Other hidden economical drains to be considered include the cost of storage space necessary to warehouse a variety of special-color styrene powders. The variety of special color materials purchased ahead of releases or left in excess after job completion, represents working capital which might be used to better advantage in other areas. Often molders purchase an additional 2 or 3% of special colors to provide insurance against anticipated rejects. After several months the scrap barrel represents a sizeable investment, whether the rejected parts are reground or not.

Within limits, painting can cover minor mold defects and irregularities eliminating costly down time and mold polishing costs. If mold scratches and sprue marks are not too deep, paint will hide them nicely. Flow lines can be easily hidden as well as the molders constant enemy—dust.

Another factor to be considered is the increased color range which paints offer over molded colors. It is difficult to mold metallics and achieve uniformity of color and a sharp or pleasant appearance. Flow lines, bad enough with straight pigments, are intensified many times with metallics. Mold scratches and particle size limitations can also be problems.

Often a molder may wish to "dry color" neutral stock to achieve color. Unquestionably, dry coloring of neutral stock has a definite place in the scheme of modern molding. At the time this practice came into use, dry coloring provided a practical way to cut costs and still color styrene. While popular color requirements were fluid and changing, they can not be compared to today's complex, off-beat and imaginative high-style colors. In the field we are discussing primarily—that of specially-matched colors in wide variety—dry coloring falls short of the results that can be obtained by painting. Basically, dry coloring is another way of coloring plastic parts before molding. As a result, in addition to the problem caused or intensified by dry coloring, all other molding causes for rejects are still present. Since the color is added to the plastic before molding, the usual rejects caused during molding—color spreads, scratches, flow lines and sprue marks—are still present. In addition, press purging costs continue to be prominent when color changes are necessary.

However, dry coloring—particularly in items where an exact color match is not important—continues to be a valuable process for the molder who has use for it. Here again, it is a question of balance—dry coloring is valuable where useful. It has a place in production just as do specially-matched plastic powders and painting. It takes a combination of methods to meet today's highly specialized requirements for sophisticated color.

The idea of painting instead of molding in color does not interfere in any way with additional decorating for multiple color appearance.

We have attempted to present a factual picture of the uses of painting instead of molding in color, and trust this information will be of value to all concerned with plastics decorating, where both small quantities of material and special colors are involved.

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Table I. Basic Calculations

ASSUME:

Specific gravity of polystyrene—1.05
Density of polystyrene—65.5 lbs. per cubic foot
Averaging wall thickness of polystyrene molding —1/8"
Paint mileage—250 square feet per gallon

CALCULATIONS:

1. Paint mileage expressed in equivalent volume of molded polystyrene:

$$\frac{\text{250 sq. ft.}}{\text{gallons}} \text{ (paint mileage)} \times 1/8\text{" (wall thickness)} \times 1/12 = 2.6 \text{ cubic feet of molded polystyrene per gallon of paint.}$$

2. Paint mileage expressed in equivalent pounds of molded polystyrene:

$$\frac{\text{2.6 cu. ft.}}{\text{gals.}} \times \frac{\text{65.5\#}}{\text{cu. ft.}} = 170.3 \text{ pounds of molded polystyrene per gallon of paint.}$$

3. Reciprocal of 170.3 lbs./gal. is:

$$\frac{1}{170.3} = .00589 \text{ gallons of paint required to paint a pound of polystyrene}$$

4. Average surface area of part molded from one pound of polystyrene:

$$\frac{\text{65.5\#}}{\text{cu. ft.}} \times \frac{\text{1 cu. ft.}}{\text{1728 cu. in.}} = 26 \text{ cu. in. per pound}$$

$$\frac{\text{26 cu. in.}}{\text{\#}} \div 1/8\text{" (wall thickness)} = 208 \text{ square inches of paintable area per pound of polystyrene}$$

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Compounding and Processing Rigid Vinyl Sheets

This article discusses processing variables such as stabilizing systems, lubricants, pigments, and resins.

Rigid vinyl sheets are produced either by calendering of extruding methods. This article describes the compounding and processing of rigid vinyl sheet by the calendering method.

Compounding

Resins—A rigid vinyl compound consists of resin, stabilizer, lubricant and pigments. The physical and chemical properties of the sheet depend almost entirely upon the resin selected. This is not the case in flexible vinyl stocks where, more than often, the plasticizer selection influences the physical and chemical properties of the sheet.

The rigid vinyl sheet compounder has three types of resins from which to choose:

1. The medium and low molecular weight resins (specific viscosity range of .47 to .31), identified as Type I PVC resins.
2. The "modified" medium molecular weight resins, identified as Type II PVC.
3. The copolymer resins of vinyl chloride-vinyl acetate, identified as co-polymer vinyl resins.

The Type I PVC resins yield a rigid vinyl sheet characterized by excellent chemical resistance, a high heat deformation temperature, and normal impact strength. The Type II PVC resins yield a rigid vinyl sheet having good chemical resistance together with high impact strength. A Type II PVC resin is commercially available or can be made by the physical blending of Type I resins with acrylic modifiers, or chlorinated polyethylene, or various polymers of styrene-acrylonitrile-butadiene. Co-polymer rigid vinyl sheets have excellent heat forming characteristics as well as a calender finish surface that readily accepts printing inks.

In general, all three classes of vinyl resins are characterized by toughness, non-flammability, good light stability, good abrasion resistance, good electrical properties and ASTM heat distortion ratings between 142°F to 167°F, at 264 psi fibre stress. The ultimate end use of the sheet dictates the resin selection. Table #1 lists some of the most important properties of rigid sheet:

Stabilization

All vinyl resins are subject to heat degradation during processing. The stabilization of a rigid vinyl stock must be carefully considered since the processing temperatures required are very near the decomposition temperature of the resin.

A good rigid vinyl calendering compound must be cap-

Table I. Typical Properties of Rigid Vinyl Sheets

Resins	Type I	Type II	Copolymer vinyl chloride-vinyl acetate
Tensile strength-psi	7,400 to 9,000	6,000 to 8,000	6,000 to 9,000
Flexural strength-psi	13,000 to 14,000	10,000 to 11,000	12,000 to 17,000
Compressive strength-psi	9,000 to 12,000	8,000 to 10,000	10,000 to 12,000
Rockwell Hardness, R. Scale	100 to 110	90 to 100	90 to 110
Shore Hardness, D. Scale	80 to 90	75 to 80	75 to 85
Izod Impact strength-ft. lb./in. of notch	.4 to .8	15 to 17	.4 to 20
Heat Distortion temp. °F at 264 psi	165 to 167	152 to 155	142 to 158
Flammability	Self Extinguishing	Self Extinguishing	Self Extinguishing
Resistance to concentrated acids & bases	Very Good	Good	Poor
Resistance to dilute acids and bases	Excellent	Excellent	Very Good

able of withstanding temperatures in the range of 400°F. It has been found that the stock actually reaches temperatures in that range in the nip of the calender rolls.

The compounder has many types of stabilizers from which to choose, but they are not all acceptable for rigid vinyl stocks.

Seiberling has conducted extensive laboratory mill heat stability tests on various vinyl resins and stabilizing systems. The tests were conducted on a 6 inch laboratory mill equipped with steam heating and water cooling. A roll pyrometer is used to determine the stock temperatures. Type I and Type II PVC resins are tested at 370°F. Copolymer vinyl chloride-vinyl acetate resins are tested at 320°F. Samples are taken from the mill at 5 minute intervals until a definite discoloration has occurred.

It was found that oven heat stability tests are not as reliable as mill heat stability tests. Experience has shown that resin-stabilizer blends showing no appreciable discoloration after 30 minutes laboratory milling generally prove satisfactory in production.

These tests also determined the following stabilizing systems satisfactory for most rigid vinyl sheet processing:

Organic tin (mercaptide), organo tins, polymeric organic tins.

Various barium-cadmium fatty acid soaps, alone or with chelating agents.

Basic lead carbonate and dibasic lead phosphite.

The incorporation of a liquid stabilizing agent is accompanied by a lowering of the heat deformation temperature of the rigid vinyl sheet.

The end use of a sheet should always be considered when one chooses his stabilizing system.

Lubricants

Rigid vinyl compound must contain a lubricant to insure release from the mill and calender rolls. The lubricant in a rigid vinyl stock also serves as a means for preventing frictional heat build-up in the stock. The lubricant level in a rigid vinyl stock can be as high as 2 phr. Stearic acid, calcium stearate, barium stearate, lead stearate and dibasic lead stearate are commonly used lubricants.

Pigments

Due to the high processing temperatures involved, heat stable pigments should be used. The following pigments give an acceptable performance in a rigid vinyl compound:

(a) Phthalocanine blues and greens
(b) Betaozynapthoic reds
(c) Pyrazalone reds
(d) Chrome yellows
(e) Cadmium lithopone yellows
(f) EPC blacks
(g) Titanium dioxide
(h) Molybdate orange

Processing

As mentioned, rigid vinyl sheet is produced either by calendering or extruding. Typical equipment for the calendering of a rigid vinyl sheet includes an intensive mixer, two-roll mills, metal detector, calender, haul-off, rolling and cutting equipment. The calender has the limitation that it will produce a quality sheet only up to .035 inches. To produce thicker sections, one must resort to press laminating of thin gauge sheets.

Raw materials are accurately charged into a steam-jacketed Banbury mixer. It has been found that a 200 lb. mixer, equipped with a 200 horsepower motor and a rotor speed of 27 RPM, is the best for rigid vinyl mixing. The Banbury drop temperature of a rigid vinyl compound is very critical due to rapid frictional heat build-up in the stock at the instant it reaches its fluxing temperature. The fluxing temperature varies with the type resin used; however, an average stock drop temperature of 350°F is common in most rigid vinyl stocks. If the stock remains in the mixer for too long a time, even as much as 30 seconds after it has been fluxed, the stock is very apt to near the decomposition temperature of the resin.

Mill mixing of rigid vinyl invites trouble. The tremendous length of time involved in mill mixing 100 lbs. of stock, with mill roll temperatures of 320°-340°F, will use up approximately 80% of the heat stability of the stock. Since the temperature control of a rigid vinyl stock is so critical, mill mixing is not recommended.

After fluxing in the mixer, the stock is transferred to a two-roll mill in order to form a continuous sheet. This is accomplished after one or two passes through the mill. It is desirable to have the mill rolls as cool as possible and still be able to hold the stock on the mill. Typical conditions of the mill are: Front roll-230°F, Back roll-230°F, Roll clearance-125 mils or less.

The rigid vinyl compound is then ready to be made into a continuous sheet of plastic by passing the hot, fluxed mass through the calender. A calender may consist of two, three, four or more hollow rolls that are prepared for heating with steam and cooling with water. It should be noted again that the rigid vinyl compound attains temperatures in the range of 400°F at the nip of two calender rolls. Therefore, it is most desirable to use a calender with the least number of rolls possible and still be able to maintain good gauge control on the sheet. Both the three and four roll calenders have proved successful in rigid calendering operations. Typical calender roll temperatures are from 280°F to 370°F. The copolymer resins fall in the lower temperature range while the PVC resins fall in the upper range.

The haul-off equipment need not be elaborate, but it must be adequate to allow possible matting, polishing, or embossing of the sheet as it comes from the calender. Large cooling drums should be included to insure a flat sheet. The rigid vinyl sheet can be rolled or cut to size.

Thicker sections are produced by laminating several sheets of thin gauge stock under heat and pressure. Press-lamination of PVC sheeting requires that the laminates reach a temperature of at least 350°F under 400-500 psi pressure. Lamination of copolymer vinyl chloride-vinyl acetate sheet also requires 200-300 psi pressure at temperatures between 280°-320°F depending upon the vinyl chloride content of the resin or resins; the higher the vinyl chloride content, the higher laminating temperature required.

Rigid vinyl sheets of PVC Type I and Type II can be heat formed, machined, cemented and hot-gas welded. The sheets, being extremely resistant to strong acids and bases, are used in industries where corrosion resistance is of prime importance. Some common applications include chemical resistant duct work, plating tanks, exhaust fans and plastic PVC pipe fittings.

Rigid vinyl sheets of copolymer vinyl chloride-vinyl acetate are easily heat formed, cemented, machined and readily accept printing inks. These sheets are used in such items as luggage, relief maps, playing cards, credit cards, lighting fixtures, skin packaging, display signs and a host of other every day items.

Conclusions

Recent developments in the rigid vinyl copolymer sheet, such as improved impact strength, higher heat deformation temperatures and greatly improved light stability, have created new end uses for the sheet. With new developments being made in rigid PVC, as well as copolymer vinyl sheets, still further growth in rigid sheet applications will be realized.

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Calendering Vinyl Film?

Here are Tips to Help Overcome the Problems

The proper temperature is important in order to obtain the best properties in the film. A good general rule is to process at the highest temperature just short of burning so that a strong, streak-free film can be obtained. The proper formulation comes into play again since there may be some problems in getting the film to release from the calender roll. Heat stabilizers and lubricants contribute greatly toward the proper release. **Large amounts of lubricants might be desirable but not possible when considering that too much might detract from subsequent printing or heat sealing.**

Since temperature is very critical it is obvious that a good system of temperature control is important. Before considering the system of control, it should be recognized that frictional heat is generated when the plastic banks of material roll prior to being squeezed between the rolls. It is normally the case that when calendering faster than about 35 yards per minute, frictional heat build-up makes it necessary to take heat out of the film. Below that speed heat must be used to get the proper flow of the plastic. This critical speed varies with the type of material so that great flexibility of control is necessary. The system then must be capable of giving uniform heat to the calender rolls or of taking it away from them.

To get the best results, the calender rolls are drilled near the surface so that hot water can be circulated through these drillings. Circulating high pressure hot water systems are the most common as they are capable of close temperature control. By pumping controlled temperature water at a rate of at least 50 gallons per minute through the drillings, uniform temperatures are obtained and since the drillings are near the surface, quick response is possible.

Controlling Thickness

In making calendered film, very high pressures are obtained at the bite. These pressures are high enough that the rolls bend and, of course, the higher the pressure the greater the bending. It is easy to see that stiffer films will generate greater pressure than will the thinner ones. Because of this and because of the greater variety of stiffnesses and thicknesses, some thought must be given to the control of this bending which produces uneven thicknesses.

Film thickness has become an important factor in the making of quality vinyl film. Continuous checking is normally done during processing in order to control the longitudinal as well as the transverse thickness variation. Longitudinal consistency is important in order to obtain uniform fabricating. As an example, close control is necessary for dielectrically heat sealing in order to make good seals at the lowest possible costs. Variations in thickness may mean changes in the heat sealing operation—not efficient operation.

While the above two thickness factors are important, the transverse contour is even more important. The uniformity of the thickness contour will determine how flat the film will be when spread out on the cutting table. Let's examine the reason for this and find out what can be done to produce an even, flat material. Since film is made in rolls of 200 to 500 yards, a large number of layers are piled up. If the film is thicker in one section than in another, it will build up more and the finished roll will be larger in this section than in the others. This means that the film in this section is stretched more. To accentuate the problem, the thinner or looser sections will be able to shrink more than the heavy sections. It is obvious then that when laid out, the film will be baggy and loose in this heavier section while it remains smooth and tight in the thinner areas.

Beta gauges are frequently used to check continuously on the thickness or rather on the weight in varying areas. Normal practice is to have one or two gauges traversing the width of the film and recording the weights on a chart.

The Beta gauges are good for determining the weight of a given area but they are not the complete solution to a uniform roll of film. In the case of embossed film, for example, it is very likely that the embossing will be deeper in the center than on the edges. This will make the overall thickness of the film in the center greater than that on the edges. If the Beta gauge shows the film to have an even weight, then the roll of film will have a greater diameter in the center than on the edges due to this deeper embossing. This means film tight on the edges and baggy in the center. To control this, it has been found necessary to measure the circumference of the finished roll in several places in order to stay within limits on bagginess.

The first method used to help to make flat film was to grind the last two calender rolls with a crown such that the diameter at the center was greater than at the edges. Thus, when the rolls bent under the pressures previously mentioned, the opening between the rolls became even. This is a good method if only one product is made but when considering the variety of pressures, it is obvious that something else is necessary.

One method used, though not extensively, to make adjustments in thickness contour is with temperature control. Infrared lights can be positioned in areas of heavy film to heat the roll more and thus expand it in order to thin down that section.

Another method that is used to compensate for variations in transverse thickness contour is the cross axis. Here the axis of one roll is rotated in relation to the axis of the other such that the edges open up slightly. If the center of the film is thicker than the edges, crossing the rolls will correct by thickening the edges. To get the proper control, the rolls are originally crowned to run a flat film of the thickest and softest formulation. Then as the film is stiffened or made thinner, the axis is crossed to open up the edges.

A third method for adjusting the thickness contour is by means of a roll bender. In this case, an extra set of bearings is placed outside the main bearings on the calender roll to be bent. To these bearings are attached hydraulic cylinders which can push or pull on the bearings. In this way the main bearing acts as a fulcrum and the roll can be bent by applying pressure to the cylinders.

The problems and solutions covered above are only a part of those present in the complex business of calendering good quality vinyl film. New ideas and new products are constantly diversifying the business further such that the plastics engineer has a never ending challenge.

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Low Molecular Weight Polyethylenes In Paperboard Coatings

Polyethylenes now denote a family of polymers differing widely in molecular weights, molecular weight distribution, viscosity, specific gravity and other properties. The low molecular weight polyethylene used in the experiments described has the properties shown in *Table I*. In *Table II*, there is a comparison of this polymer to higher molecular weight polyethylenes and paraffin wax. Although there are tremendous differences in molecular weights and viscosities between the various polyethylenes, such important properties as hardness and melting point are fairly close.

Low Molecular Weight Polyethylenes—have low melt viscosity and blend readily with petroleum waxes. These polymers show greater compatibility with wax and other additives and can be run at lower temperatures than the high molecular weight polyethylene. Danger of oxidation and development of off odors is reduced by the speed of solution and the lower operating temperature.

Compatibility. Polyethylene will dissolve in petroleum waxes at temperatures above 210°F. On cooling, the polyethylene separates from the wax as a fine dispersion. The cloud point for various percentages of low molecular weight polyethylene in paraffin is shown in *Figure 1*. It is necessary to keep the wax temperature at least 15°F above the cloud point for most coating applications. This eliminates any danger of the coating in the pan cooling to the cloud point as the cold board contacts the wax. Under certain storage conditions below the cloud point, the polyethylene may settle out. Higher molecular weight polyethylenes are more apt to precipitate and more difficult to redissolve if this should occur. *Figure 2* shows settling of 1½% polyethylene in dairy wax after sixteen hours at 150°F.

Hardness. Polyethylene increases wax hardness as measured by the needle penetration test. (ASTM-D1321-57T) This effect is even more pronounced at higher temperatures as shown by the data at 100 to 120°F. See *Figure 3*. At these elevated temperatures, there is a tendency of the paraffin to bloom to the surface. The greater compatibility of paraffin with low molecular weight polyethylene than with high molecular weight polymer is shown in *Figure 4*. Greater hardness is imparted to wax at 100-120°F by low molecular weight polyethylene. At room temperature, there is very little difference in needle penetration. The high molecular weight polyethylenes by themselves are slightly harder than the low molecular weight material.

Blocking. Polyethylene raises the blocking point of paraffin. Our test was run according to TAPPI-T652 sm 57. See *Figure 5*. About five percent polyethylene is usually sufficient to eliminate danger of blocking during summer weather in this country.

Table I. Properties of A-C Polyethylene 6

Molecular Weight	2000
Softening Point—°F	225
Congealing Point—°F	215
Specific Gravity 75°F	0.92
250°F	0.77
Needle Penetration—1/10 Mm	3.2
Viscosity—CPS. 250°F	200
300°F	130

Table II. Comparison of Paraffin and Polyethylene

Material	Molecular Weight	Viscosity CPS at 284°F	Melting Point °F	Hardness 1/10 Mm
Paraffin	360	2	134	15.0
Polyethylene	2000	180	216	3.2
Polyethylene	12000	100,000	225	3.0
Polyethylene	21000	63,000,000	230	2.5

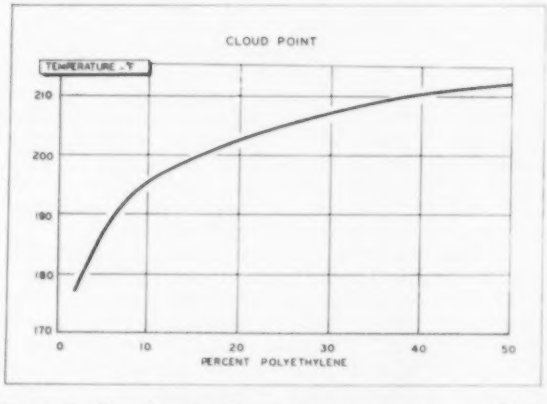

Figure 1. Cloud point for various percentages of low molecular weight polyethylene in paraffin.

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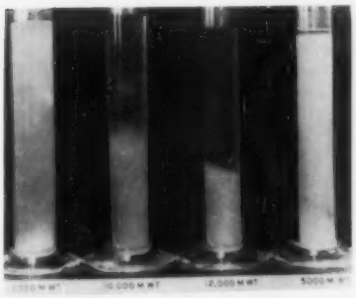

Figure 2. Settling of 1½% polyethylene in dairy wax after 16 hours at 150°F.

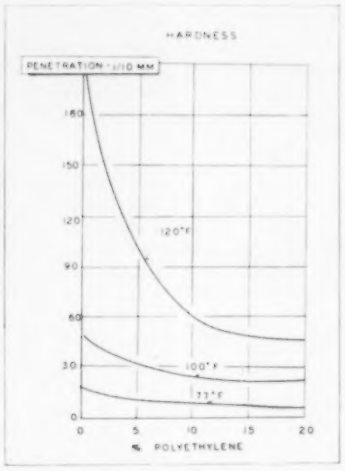

Figure 3. Polyethylene increases wax hardness.

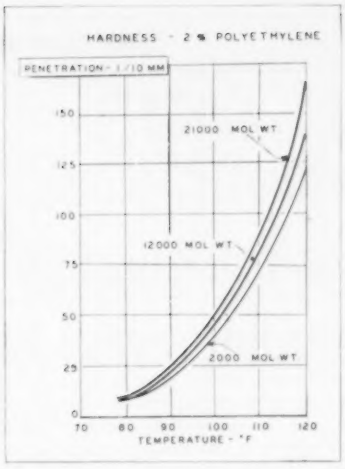

Figure 4. There is greater compatibility of paraffin with low M.W. than with high M.W. polymers.

Scuff Resistance. One of the most important properties imparted by polyethylene to wax is the improvement in abrasion resistance. Unfortunately, there is no standard method for measuring this property of coated paper and many methods are in use. The results obtained with a Taber Abrader are shown in *Figure 6*. These tests were run at 74°F and the improvement imparted by polyethylene to paraffin is even more pronounced at higher temperatures.

Water Vapor Transmission Rate—of a wax-polyethylene blend is poorer than paraffin when tested flat at 100°F and 95% relative humidity. However, field packaging tests frequently show the blends to be superior because of better scuff resistance, flexibility and heat seal. Laboratory water vapor transmission tests are usually run on perfect samples which are carefully handled during testing. The results are the best obtainable with the particular coating. Field results fall short of the predicted values by varying amounts depending on how the package responds to handling, temperature changes and aging.

Chemical Resistance. Polyethylenes are well known for their chemical resistance and are frequently added to waxes to improve this property. It is obvious that no appreciable chemical resistance can be obtained unless the coating is free from pinholes. We have seen failures attributed to lack of resistance of the coating, but closer examination indicated the difficulties were due to pinholes in the coating. A slight change in the material packaged may result in failure of a previously successful coating. A bakery changed the pan oil from straight mineral oil to one containing seven percent cottonseed oil. Although, the oil remaining on the baked goods was only a small percent, grease failure of the package occurred in two days. It was necessary to change the coating formulation to obtain the desired five days resistance to grease.

Tensile Strength and Flexibility—of paraffin wax is increased by the addition of low molecular weight polyethylene reaching a peak with about 20% polymer. The exact maximum varies with paraffin, shape of molds and rate of elongation. Not only is room temperature tensile improved, but also tensile strength and flexibility at low temperature, such as would be encountered in a refrigerator or deep freeze. Tensile strength, flexibility and adhesion to the board determine the behavior of the coating to scoring, forming and denting. If the coating is too brittle, cracking and flaking occurs. This is usually more pronounced at low temperatures.

Adhesion—to nonporous or slightly porous substrates is a problem which can be helped by the addition of some tacky microcrystalline waxes and resins. Before the advent of polyethylene, these tacky materials had limited application for surface coating because of low blocking point and poor slip. The polyethylene can be used to counteract these deficiencies.

Coating Weight and Distribution—is changed by the addition of polyethylene because of the increased viscosity and higher congealing point. The polyethylene reduces pene-

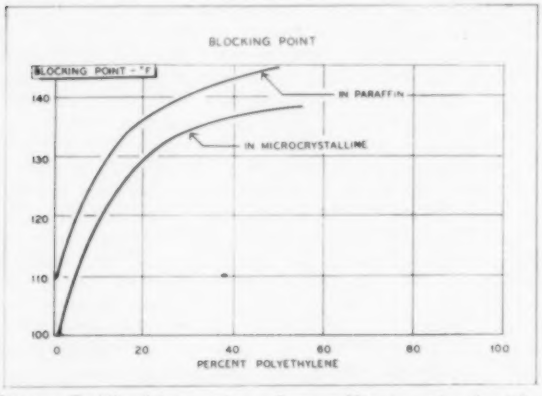

Figure 5. Blocking point of paraffin is raised with polyethylene.

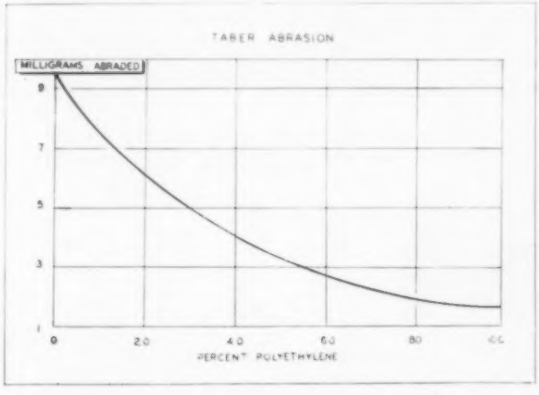

Figure 6. Improvement in abrasion resistance.

Table III. Gloss

% Polyethylene	20	40
Speed—Fpm	Gloss	
Untreated	26	35
25	29	40
30	34	42
35	45	48
40	38	55
45	—	52

tration into the board and this often results in substantial reductions in total wax consumption, even though the amount of surface wax is usually increased. These changes are more pronounced on porous stocks. Results obtained on corrugated board coatings with high percentages of polyethylene added to paraffin show that coating weight decreased with increasing percentages of polyethylene until the viscosity limitation of the waxer was reached. With the straight paraffin coating, only 10% of the wax remained on the surface. With 60% polymer in the coating, the surface wax was 80% of the total coating weight.

Coating Methods. The low molecular weight polyethylenes lend themselves to coating by conventional waxing techniques. The coating temperature generally has to be raised over that of straight wax to assure that the polyethylene will remain in solution. Harder rubber rolls and greater pressure at the nip will keep the coating weight down to the desired value. Heated polishing rolls, rods or blades help in obtaining a smooth coating surface. These changes are very minor and we will not spend more time on the details.

High Gloss Coatings. There is always considerable interest in improving gloss for frozen food and other quality packages. The conventional method for obtaining high gloss on wax-polyethylene blends is a cold water quench. This produces a good gloss but the surface is marred by flow lines which occur when the molten coating contacts the water. Various techniques are employed to reduce these surface irregularities, but the complete elimination has been very difficult.

Several new methods are now being used to obtain higher gloss. One procedure involves casting the coating against a smooth, highly polished roll or belt.

Another method for obtaining high gloss is by subjecting the coating to a surface heat treatment and then allowing the coating to air cool. The desired effect can be readily illustrated by holding a lighted match under a wax-polyethylene coating. The coating is melted and then resolidified. The center portion will be dull and there will be a halo of very high gloss. Beyond this area, the gloss decreases to that of the orginal coating. It should be noted that the dull center is not due to lack of wax but rather to the coating rate. In our laboratory, we have obtained high gloss by subjecting a coated web of paper to a heat treatment from radiant heaters or hot air. A gas flame can also be used. Using two radiant heaters (600 watts each, 16½ inches long and 4½ inches from the web); maximum gloss was obtained at a running speed of 40 feet/minute (Table III). At lower speeds, the coating was driven into the paper and at higher speeds there was insufficient heat capacity to melt the coating. By enclosing the heating section and using more heaters, commercially acceptable speeds should be obtainable.

The width of the glossy section was dependent on the viscosity and melting point of the blend, and the compatibility of the polyethylene with the remainder of the coating.

Many converters and equipment manufacturers are doing considerable research into high gloss coatings and developments should be rapid during the next few years.

One Hundred Percent Polyethylene Coatings—of the low molecular weight type are being run on conventional waxers but this is the upper limits of this type of coater. When the low molecular weight polymers are modified by the addition of 10-12,000 molecular weight polyethylene, it is necessary to use hot melt coating equipment. There is a wide variety of coaters available but these break down into two general categories. In one, an excess coating is applied to the paper and the excess removed by doctoring with rolls or blades. In the other system, the coating is reduced to the desired thickness prior to application by means of metering rolls or doctor blades. In the range of 5,000 to 10,000 centipoises, we believe the latter method is preferable because it is very difficult to doctor off excess viscous coatings at high speeds.

A 50-50 blend of a 2,000 and 12,000 molecular weight polyethylene was coated on a reverse roll coater of the design shown in Figure 7. The coating temperature was 280°F and the viscosity was 9,000 centipoises. Coatings of ¼ to 3 mils thick were obtained by varying the machine settings. The functional properties of the flat coating approached that of polyethylene film. The creased chemical resistance and creased water vapor transmission rate were poorer than that of polyethylene film. Resins can be added to improve adhesion to nonporous substrates such as foil and glassine and also to increase heat seal.

Applications—for polyethylene in board coatings are numerous and only a few of the main uses will be covered.

Corrugated Board Cartons are coated with blends containing from 10 to 90% polyethylene with the usual about 20%. The higher setting point and increased viscosity reduce penetration into the board and often result in substantial reductions in wax consumption. The increase in surface wax helps to eliminate fiber scratching The main application has been for packaging appliances and furniture. The lack of fiber scratching and good scuff resistance have, in some cases, eliminated the need for cellulose wadding cushioning. The excellent release properties permit the packaging of such tacky materials as synthetic rubber. Good chemical resistance, particularly at warm temperatures, has permitted the use of these coatings for many items which could not be packaged in an unmodified wax coating. Other uses include milk containers, and food boards.

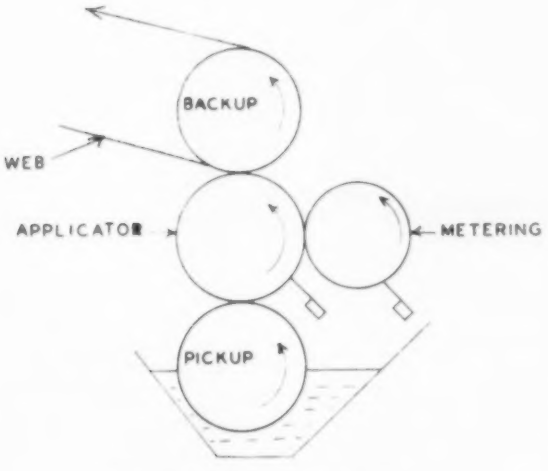

Figure 7. Reverse roll coater.

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Epoxy Resins for the Encapsulation of Electronic Components

The design engineer, aided by improved technical data from the vendors and persistent education and counselling by the chemists, has become well acquainted with encapsulating materials.

The increased demand for epoxy resins has brought the price down to the point where it becomes feasible to consider their use in broader encapsulation applications. Advances in compounding and processing technology have made their cost per unit volume quite attractive. The finished product also has an attractive appearance which promotes its marketability.

Table I. Requirements for Casting Materials: 90°C Service

Property of Mixed Material	Acceptable Value
Viscosity vs. time at 24°C	5000 cps for 20 minutes
Internal heat rise vs. time for different masses	Maximum temperature in center of 1" and 2" cubes, in plastisol mold not to exceed 90°C. Lower temperatures than this are most desirable.
Time to gelation (removable from mold) at room temperature	One hour. Surface must not be tacky.
Time vs. temperature for full cure	Ultimate properties in 48 hrs. at R.T. or 1 hr. at 60°C.
Shelf life of unmixed raw materials	Minimum of six months.
Toxicity	Non-toxic in normal chemical handling.
Cost	Basic materials .65/lb., (.40/lb. preferred).
Mechanical strength, nominal, psi	
tensile	5 -10,000
compressive	12-15,000
flexural	6 - 8,000
Dielectric strength, v/mil	300
Dielectric constant	4.8
Power factor, %	3.0
Flammability	Self-extinguishing
Thermal conductivity	Measured after selection of material is made.
Thermal shock	Withstand cycling from −65° to 90°C, MIL-I-16923B
Specific Gravity	2.0 maximum
Compatibility	Compatible with 90°C insulations likely to be used.

To broaden the use of epoxy encapsulants, the chemist has been pursuing development programs whose purpose has been to formulate materials and tailor them to the specifications set forth by the electrical and mechanical engineers.

When the product line of General Electric's electronics department was expanded to accommodate new units, two questions concerning encapsulation arose. The one which was quickly resolved was where the encapsulation was to be done; on the outside or within the department. It was decided to process the units internally for control and delivery commitment reasons. The second question concerned the development of formulations. Some thought had been given to approaching a vendor with the idea of his developing and certifying materials to meet the department's specifications. However, when the anticipated ultimate volume of the line was viewed in full, it was realized that the scope of the required program would be broad and quite unprofitable for the vendor in proportion to the return he would realize in sales of rather small quantities of several different compounds. It was also felt that it would be advantageous to develop formulations internally, thus keeping them under efficient quality control.

Objectives and Scope

Originally the objective adopted for this work was that of the formulation and recommendation of a relatively inexpensive, easily handled, easily controlled material for potting, encapsulation and impregnation of electronic equipment which must operate over the range of -65°C to 90°C. There was also some hope of making progress toward 105° and 130°C formulations. The material was expected to be processed by metering equipment and in general, was not intended to meet unusual electrical or mechanical needs.

The origins of the above temperature figures lay in the Standards and Manufacturing Engineering Sections of the

Table II. Materials Tested During the Program

Material	Type	Price $/lb.	Remarks
Ciba 6010	Epoxy	0.86	Unmodified liquid epoxy in the 15000 cps viscosity range.
Epon 828	Epoxy resin	0.86	Same as above
Epon 820	Epoxy resin	0.86	Low viscosity epoxy resin which contains some reactive points.
ERL 2774	Epoxy resin	0.86	In current LME inventory: should be used wherever possible.
Piccotex 100	Coumarone	0.22	Light amber solid, mp 100°C.
Transphalt	Hydrocarbon resin	0.05	Low Cost flexibilizing extender.
Cardolite	Furfural resin	0.40	Low melting, low viscosity, dark brown reactive resin.
No. 629 Whiting (Rambo No. 1)	Calcium carbonate	0.048 (in 500 lb. lots)	Low cost dry-ground limestone.
No. 133 Slate Flour	Complex aluminum silicate	0.046	Low cost silicate filler.
Atomite	Calcium carbonate	0.0512	Wet ground limestone.
T-60 Tabular Alumina	Aluminum oxide	0.10	Inert mineral filler
Diethylene triamine	Primary aliphatic amine	0.43	Short pot life, room temperature reacting hardener.
Triethylene tetramine	Primary and secondary amines	0.51	Similar to above: longer pot life.
Diethylamino propylamine (Shell Curing Agent A)	Primary and tertiary aliphatic amine	1.50 in 5 gal. lots	Similar to both above: appreciably longer pot life.
Methyl nadic anhydride (MNA)	Acid anhydride adduct	1.25	Long pot life at R.T. Requires elevated temperature cure.
DMP-30 (Tridimethyl amino methyl phenol)	Tertiary amine	1.75	Accelerator to shorten cure time of MNA systems.

Department concerned, and were adopted from (a) AIEE temperature classifications, (b) MIL-I-16923B, and (c) processing, handling, and end-use requirements of the production department.

Although the experimental scope was limited essentially to the 90°C requirements, some attention was necessarily given to the higher temperature classes, and ultimately a degree of process was made in the direction of the 105° and 130°C materials as will appear later.

Since the method of handling (automatic metering equipment, and the general needs could be specified, a table of requirements was drawn up (Table I).

Materials Considerations

At the outset, low cost was held to be the most important factor to be considered, and the initial experimental work was carried out accordingly. Vendors' technical literature, prices, and samples were obtained and raw materials selected to be formulated.

Since specific data concerning specific requirements were requested in a program of closely defined size, only a limited number of potentially suitable materials could be experimented with. However, this does not imply special endorsement of any materials used, or exclusion, due to inadequacy, of other materials not named. The data recorded here is a compilation of objective facts.

Preliminary data on the raw materials selected for study are contained in Table II, above.

In order to guarantee an efficient wetting and impregnation of the structures which were to be encapsulated, a readily flowable compound was desired. This meant that the viscosity should be observed and set at an optimum figure. Past experience dictated that a figure of 5000 cps at 24°C would most likely be the maximum. Therefore,

Table III. Critical Properties of Hardeners for 90°C Service

	Boiling Point, °C		Vapor Pressure (20°C)	Viscosity, cps	
Diethylenetriamine	206	760 mm Hg			
(DETA)	123	50	0.2 mm Hg	7.1	20°C
	86	10			
Triethylenetetramine	277	760 mm Hg	0.01	26.7	20°C
(TETA)	183	50			
	144	10	1.2	2.4	0°C
Diethylaminopropylamine	169.4	760 mm Hg			
(DEAPA)		50		1.4	20°C
		10		0.94	40°C

Table IV. Specific Gravity of Raw Materials

Material	Specific Gravity
ERL 2274	1.16
Epon 820	1.16
Epon 828	1.16
DETA	0.9542
TETA	0.9818
DEAPA	0.8289
Cardolite NX 3159	1.18
Ground Limestone (No. 628 Whiting, Rambo No. 1)	2.71
Atomite	2.71
Slate Flour	2.80
Aluminum Oxide	3.70

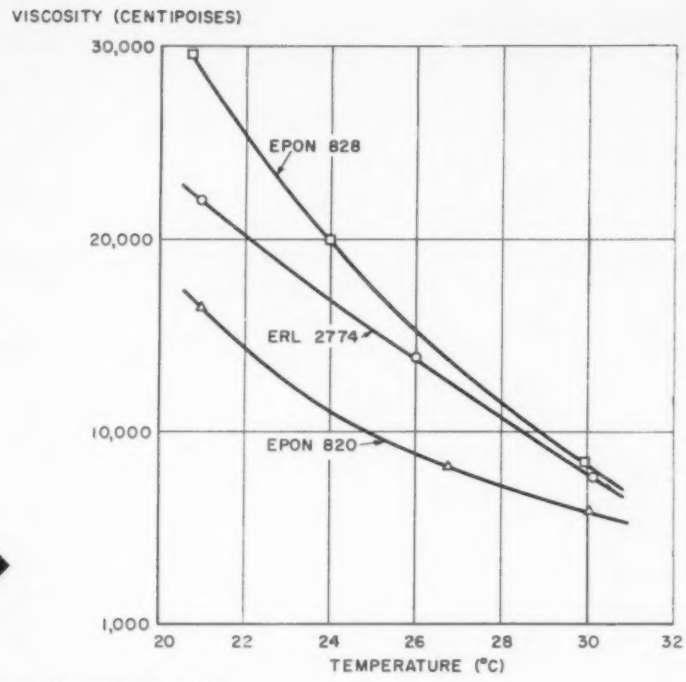


Figure I. Viscosity of three typical liquid epoxy resins over a standard working temperature range.

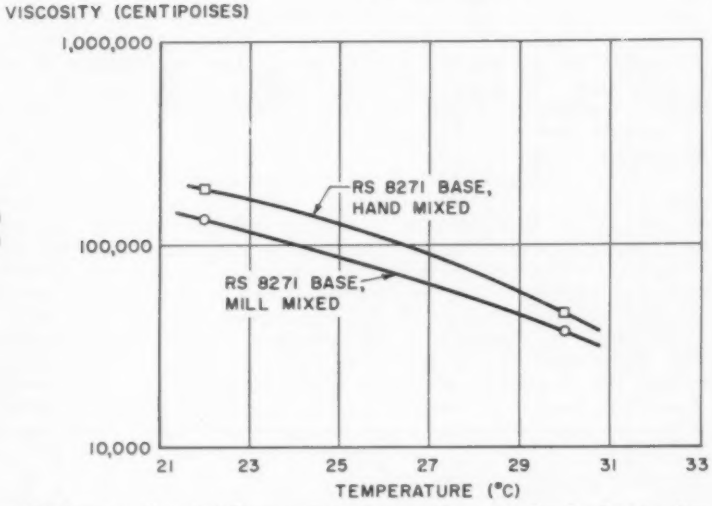


Figure II. Difference in viscosity between hand mixing and mill mixing on an epoxy resin-filler system.

the viscosities of the raw materials and compounded formulations were checked at room temperature and, in some cases, over a range of temperatures. The viscosities were determined with the Brookfield Viscosimeter Model RVM.

Table III lists the boiling points, vapor pressures, and viscosities of the three hardeners considered for 90°C service.

Table IV notes the specific gravities of some of the standard raw materials utilized in this program.

Discussion

The low-cost coumarone-indene extender resins, Piccotex 100 and Nebony 100 would not dissolve in the epoxy resin ERL2774 even when the resin was heated gradually from 28° to 120°C, and were therefore abandoned.

Cardolite NX3157 was claimed to be compatible with epoxy resins. Since it showed low viscosity, 500-750 cps at 25°C, it seemed to be a promising extender for otherwise viscous, highly-loaded epoxies. The material did not cure by itself through reaction with conventional hardeners, but did have a "Pseudo-epoxide equivalent" of 100 when present in an epoxy-hardener system. Thus, when it was added to an epoxy, enough extra hardener had to be used to cross-link fully all reactive groups. Thus, for example, in a one-to-one mix of NX3157 and Epon 828 (epoxy equivalent about 200), 24 parts of Curing Agent A would be required, 8 for the Epon and 16 for the Cardolite.

The Curing Agent A was selected for study because the properties imparted by its cure appeared to meet the requirements of both Class A and Class B of the specifications. Also of note was the ease of handling of this low viscosity 1.9 cps at 20°C. liquid and the satisfactory pot life, (3 hrs. at room temperature) for dispenser type processing. In loaded systems, this was found to be lengthened to as much as twelve hours. At 60°C. the loaded system (RS8264) was hard after one hour. The supplier recommended 90 minutes at 60°C. for complete cure of a curing agent A system. However, for test purposes, additional time was allowed to ensure completeness of cure beyond any doubt. Likewise,

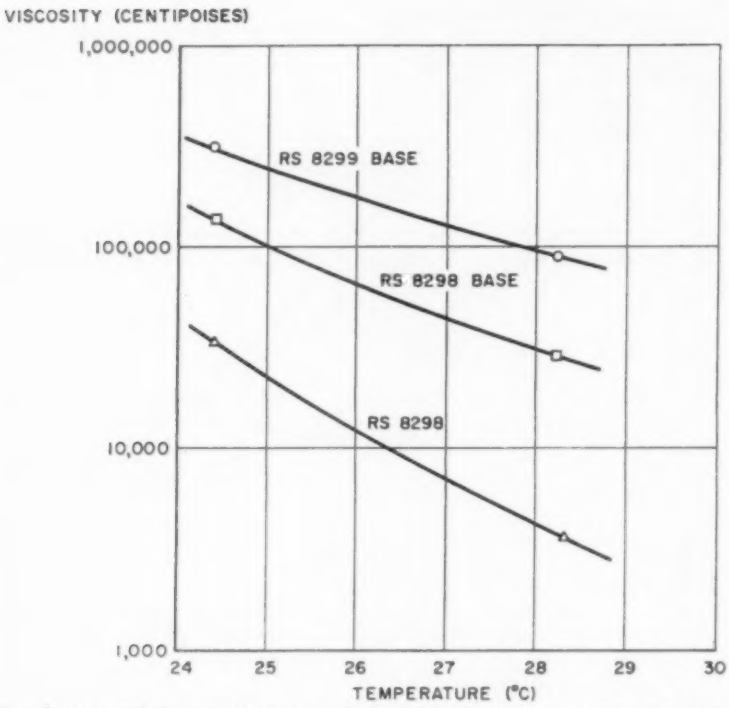


Figure III. Viscosity changes of an epoxy-filler system with filler content and hardener addition.

in order to produce completely homogeneous and void-free test samples, double milling and de-airing were instituted. In production, a satisfactory procedure would most likely be to pre-mix all the ingredients except the hardener, blend, and introduce the blend and the hardener into the respective reservoirs of the dispenser. The warming and de-airing would be accomplished by the machine during the subsequent processing.

Cost was not, at the moment, a critical factor. Rather, instructions were that efforts should be expended in devising a formulation which could be mixed, cast, and cured at room temperature. The ability to mix and cast at room temperature would minimize the danger of incapacitating the metering and dispensing in an inadvertent stoppage. This might occur during high temperature processing, through the compound's setting up in the lines, mixing chamber, or heads. Low temperature processing with the 60 minute cure specification would also serve to reduce the need for costly ovens, and minimize the cost of molds.

The low-temperature processing objective dictated the choice of the reactive primary amines for the next stage of the work. However, this very reactivity made necessary a series of time temperature studies on castings of various sizes, *Figures IV to IX*. Cubes 1x1x1 and 2x2x2 inches were chosen for these tests, following the expressed practices of LMED, even though it was considered unlikely that a volume of as much as eight cubic inches would often be encountered in an electronic package.

It was readily observed that the cure cycles of the compounds were dependent upon the amount of filler, thickness of section, and temperature of processing. This held true regardless of resin and type of hardener. The effects of these variables are also portrayed in *Figures IV to IX*. Where the filler content was increased above a ratio of 100 to 100 resin, the gel time, under room temperatures processing increased in most instances.

For example, a series of experiments were conducted wherein 30 gram samples of a mill batch composed of 100.0

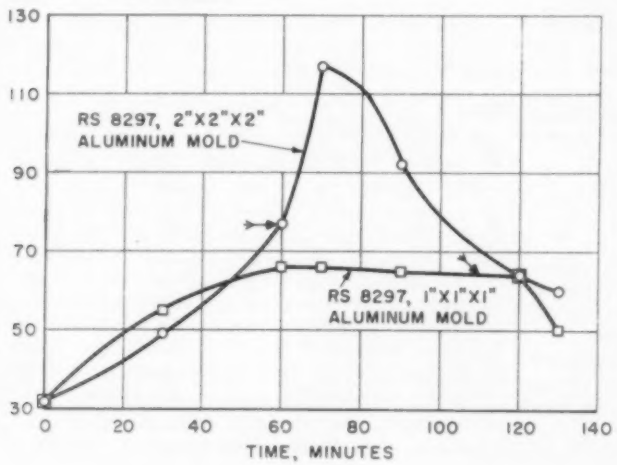


Figure IV. Comparison of exotherms of RS8297 formulation cast in 1" x 1" x 1" and 2" x 2" x 2" 3.0 mil aluminum foil molds and cured in an oven at 60°C.

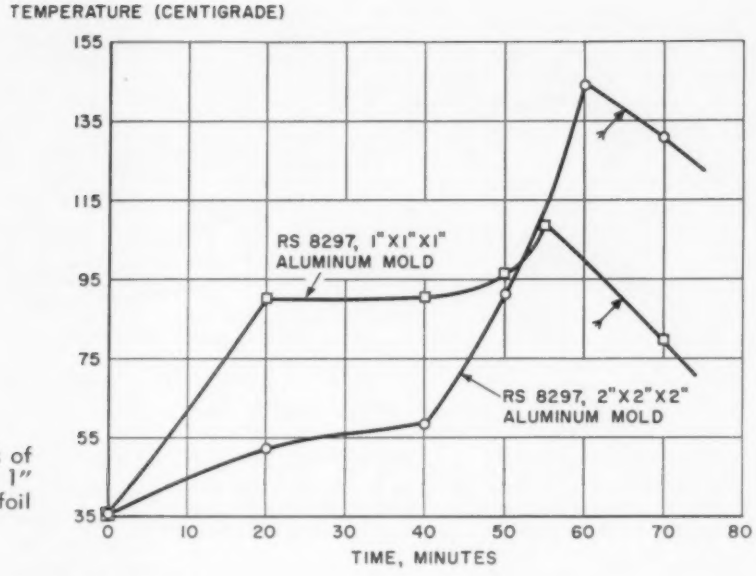


Figure V. Comparison of exotherms of RS8297 formulation cast in 1 x 1 x 1" and 2 x 2 x2" 3.0 mil aluminum foil molds cured in an oven at 90°C.

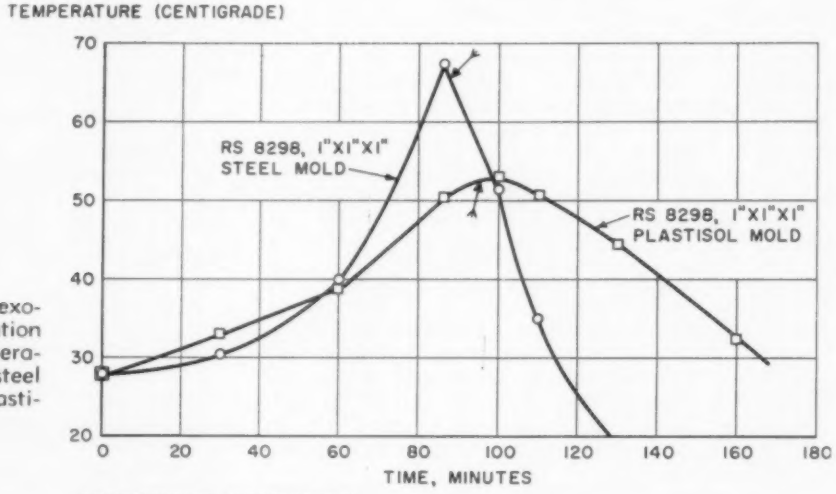


Figure VI. Comparison of exotherms of RS8298 formulation cast and cured at room temperature (28°C) in 6.0 mil wall steel mold and a 0.5" wall vinyl plastisol mold.

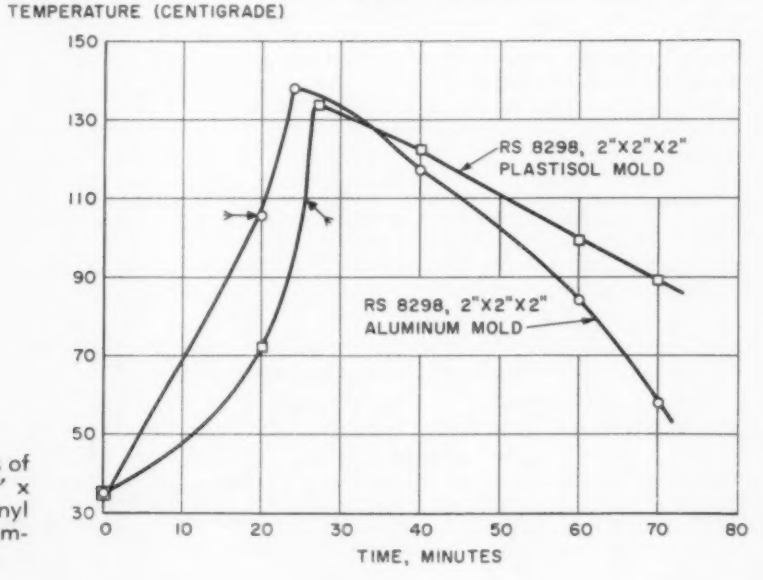


Figure VII. Comparison of exotherms of RS8298 formulation cast in 2" x 2" x 2" 3.0 mil aluminum and 0.5" vinyl plastisol molds and cured at room temperature.

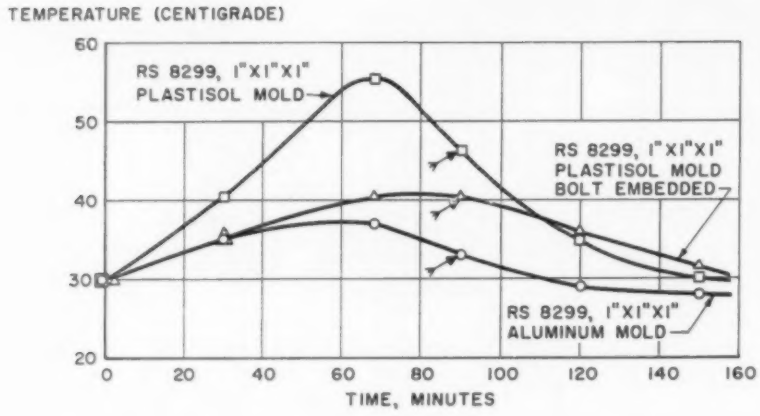


Figure VIII. Comparison of exotherms of 1" x 1" samples of RS8299 formulation cast and cured at room temperature, one in a 3.0 mil aluminum mold and two in 0.5" plastisol molds, one of the latter having a ½" x ¼" steel bolt embedded therein.

parts ERL 2774 and 200.0 parts No. 629 Whiting were cured with diethylenetriame in amounts varying from 8.0 parts per 100 resin to 11.0 parts. The mixing or processing temperatures of the samples varied from room temperature (28°C) to 45°C. In no instance was there a rise of more than 5°C in exotherm, and none was cured to a state where it could be removed from the mold in less than 1½ hours. The results were the same when triethylenetetramine was used as the hardener in similar experiments. Lowering the filler content from 200.0 to 150.0 parts per hundred resin did not decrease the time of the room temperature cure with diethylenetriamine and triethylenetetramine as hardeners. However, when the mix temperature of this type of formulation was raised to 40° to 50°C, the cure time dropped below the 60 minute specification limit.

Having observed that the decreased filler ratio had an effect on the reaction time, formulations were again made up with the low cost Cardolite and Transphalt resins using the 100/150 resin-filler ratio. Diethylenetriamine was used as the hardener and the mixing and casting performed at room temperature (30°C). None cured within an hour. A minimum of 50°C was required and then a hard gel was achieved in 35 minutes. It was also observed at this time that different types of fillers apparently affected the cure rate. In this instance, an atomite, wet ground limestone, filled formulation was tested against a No. 629 Whiting, dry ground limestone.

The formulations utilized in the exotherm studies were as follows:

RS 8297

80.0 Epon 820
20.0 Cardolite X3157
100.0 #629 limestone Whiting
9.6 diethylaminopropylamine

RS 8298

100.0 ERL 2774
100.0 #629 limestone Whiting
10.0 diethylenetriamine

RS 8299

100.0 Epon 820
150.0 #629 limestone Whiting
10.0 diethylenetriamine

RS 8300

100.0 ERL 2774
200.0 #629 limestone Whiting
10.0 diethylenetriamine

Further experimentation developed the observation that a formulation composed of

Epon 820	100.0 pbw
No. 629 Whiting	100.0 pbw
Diethylenetriamine	10.0 pbw

gave the most desirable results in processability, which appeared to be the most emphasized property at this time. This included room temperature mixing, casting and curing, viscosity, cure time, and general physical and electrical properties.

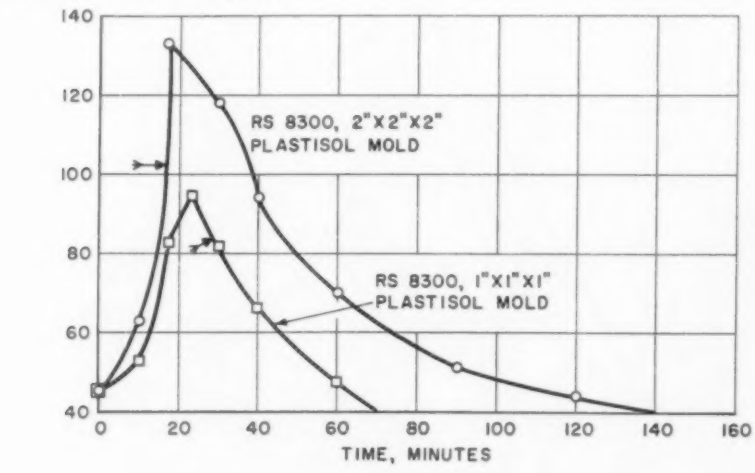


Figure IX. Peak exotherm of a 2" x 2" x 2" sample of the RS8300 formulation cast at a mix temperature of 50°C into a 0.5" wall plastisol mold and allowed to cure at room temperature (28°C.)

Table VI. Physical and Electrical Properties of Cardolite-Extended Epoxy Formulations

Property	RS8265 70/30 Blend	RS8264 50/50 Blend
Flexural Strength, psi	11,036	9,580
Tensile Strength, psi	3,988	5,093
Compressive Strength, psi	17,099	16,313
Power Factor (60 cps)	0.6	0.9
Dielectric Constant	5.6	5.6
Volume Resistivity (ohm-cm)	2.9×10^{15}	4.2×10^{14}
Dielectric Strength (v/mil)	391	410
Costs (cents/lb)	28.7	26.4

One noticeable disadvantage of this formulation was that in volumes of more than 1.25 cubic inches, the exotherm rose above the 80°C specification. In the 2 x 2 x 2" molds, peaks were measured as high as 150°C. These peaks were attained rapidly, often in 3 to 7 minutes, a time which actually constituted thermal shock. The temperatures remained above 80°C for periods as long as 45 minutes. When Shell Hardener A was used in the above system, a minimum temperature of 60°C was required to effect a gel just within the 60 minute limit. A firm gel was formed in 30 minutes at 90°C.

It was agreed at a meeting with LMED that the RS8271 formulation should be tentatively accepted, pending production trials and full performance tests, as the 90° encapsulating compound. It was further agreed that the RS8272 formulation should be accepted, on the same basis as above, as the 105°C material.

It was also suggested that the RS8271 be tested for the standard electrical properties at 23°C and 105°C. It was thought, at first, that this formulation might also suffice for the 105°C Class system. However, it was considered "safer" to retain the Hardener A cured system (RS8272) for the 105°C compound, since it was claimed to age better.

A request was also made to test the T-60 alumina as replacement for the No. 629 Whiting in the 90°C Class formulation. The reason for this was that LMED was already using this filler in existing compounds and was reluctant to add another to the inventory even though they were dissatisfied with the T-60 cost and high abrasiveness. The T-60 formulation was coded RS8274. This formulation was tested and found acceptable.

Following another discussion, it was felt that recommendations should be made for a 130°C system based essentially upon our experience and knowledge of the resins and chemicals involved. However, since a suggestion had been made to use Ciba 6010 resin and methylnadic anyhydride hardener, it was deemed necessary to run some pertinent experiments with them because of their previously untested status.

When added to a resin such as Epon 820 or Ciba 6010 MNA lowered the viscosity from about 8000 cps to about 4000, which aided processability. The conventional cure for a methylnadic anhydride-DMP-30 system was 2 hours at 80°C followed by 2 hours at 150°C. When sample RS8276, was made up and cured according to this cycle, severe warpage was observed. Therefore more samples were made up but the amount of DMP-30 was decreased from the conventional 3.0 parts per hundred resin to 2.0 parts, RS8277, and to 1.0 parts per hundred resin, RS8278. This served to prolong the cure time but did not decrease the warpage. Therefore, different curing cycles were tried using all the above formulations:

(a) 16 hours @ 60°C + 2 hours @ 150°C
(b) 2 hours @ 80°C + 2 hours @ 150°C
(c) 2 hours @ 100°C + 2 hours @ 150°C

followed by cooling to 30°C over 1 hour.
Of these the last showed only slight warpage. However, double-thickness samples, ¼ inch, did not warp under any of the curing cycles.

Also requested was an alternate formulation for the 155°C Class to replace the Tonox-PL system. This system has been partly satisfactory and this only when Teflon insulated wire and components have been used in conjunction with it. A more desirable system would be one which provided more stability and compatibility with the wire enamels, insulations, and components in the present or contemplated design of the electronic packages. It had previously been proved that amines in general, aromatic amines particularly, and Tonox especially were deleterious to and incompatible with the more desirable and economical magnet wire insulation systems such as silicones, silicone alkyds, polyesters and silicone-polyesters.

Further discussions elicited the following information:

1. The proprietary ERL 2774, T-60, Tonox-PL system will be retained by LMED pending the proving in of something better.

2. Based upon the data, knowledge and properties of the Epon 828 type resins (ERL 2774, Hysol 6040, Epon 828) it was felt that one of these should be selected as the standard base resin for all formulations.

However, since the ERL 2774 was an inventory item and the supplier certified his shipments to be within the purchaser's specification, it seemed likely that the ERL 2774 would be selected as the base resin throughout all the systems.

Some mention was made concerning materials for the Class H or 180°C systems. However, it was agreed that an experimental study would have to be made before any materials could be recommended.

For the electrical and mechanical tests, 6 x 6 x .100" samples were cast in ASTM rubber molds and on ferrotype plates. Experiments were run using thin rolled metals viz., steel and aluminum, as well as plastisol for mold construction. These tests were utilized also for the purpose of observing the thermal properties of the different thickness sections in relation to the mold construction. In some samples, steel bolts were embedded, ½" long x ¼" diam. in the 1 x 1 x 1" cubes and 1" x ¼" in the 2 x 2 x 2" cubes. Copper-constanta thermocouples were embedded in the center of the samples and the readings taken on a G.E. Thermocouple Potentiometer.

The power factor and dielectric strength samples were run at 60 cps at 500 volts, utilizing silver paint electrodes. The volume resistivity tests were run on the same samples which were used for the power factor and dielectric constant, except that the measurements were made at 500 volts DC.

The electrical test results show that the Epon 820 formulation has a slight advantage over the Ciba 6010. Over-all the MNA system shows much better properties when tested at room temperature than the amine cured systems. Thus, for the 130°C class and as a possible alternate for the 155°C class, the RS8278 system was tentatively recommended pending full performance tests.

Experimental

The first experimental formulation tried was as follows:

ERL 2774 = 100 parts by weight
Piccotex 100 = 100 parts by weight

Attempts to dissolve the Piccotex failed.

The Cardolite extended formulations were made as follows:

ERL 2774 = 100.0 parts by weight
No. 629 Ground Limestone = 200.0 parts by weight

Table VII. Electrical Properties of RS8271

Property	at 23°C	at 105°C
Dielectric Constant (60 cps)	5.66	6.62
Power Factor (% 60 cps)	0.65	4.76
Volume Resistivity (500 VDC)	6.01×10^{15} (ohm-cm)	5.52×10^{11} (ohm-cm)
Dielectric Strength	Ave. 414 (V/M)	

The ingredients were weighed out, mixed by hand, and dispersed in one pass on the three roll paint mill. The resulting dispersion was a viscous, non-pourable mixture at room temperature. It was de-aired in a heated vacuum chamber at 55°C for 20 minutes. To this mixture was added:

Cardolite NX 3157 = 100.0 parts by weight
No. 629 Ground Limestone = 200.0 parts by weight

The total mixture was then passed once through the three-roll mill. It was de-aired in the chamber at 55°C for 10 minutes. To this final mixture was added 24.00 parts by weight of Shell Curing Agent A. The whole was then de-aired again at 55°C for five minutes. This mixture was pourable at 55°C.

The samples were cured overnight at 60°C and post-cured for two hours at 110°C. The cured samples were dark brown, hard and brittle and possessed a very smooth glossy surface finish. This composition was labelled RS8264. The results of the physical and electrical tests are shown in Table VI. This table includes the results of tests done on samples made from RS8265, formulated thus:

ERL 2774 = 70.0 parts by weight
Cardolite NX3157 = 30.0 parts by weight
No. 629 Whiting = 200.0 parts by weight

The ingredients were mixed and dispersed in one pass on the 3-roll paint mill. The mixture was de-aired as above and 10.4 pbw diethylaminopropylamine added and the final mixture de-aired for three minutes. The casting and curing were the same as for the RS8264 blend.

The addition of 2% pigment grade iron oxide to the formulation lowered the volume resistivity of the RS8265 from 2.9×10^{15} ohm-cm to 3.7×10^{14} ohm-cm.

The RS8271 formulation was made up as follows:

Epon 820 = 100.0 pbw
No. 629 Whiting = 100.0 pbw

The ingredients were mixed and dispersed one pass on the paint mill. To the mix was added:

Diethylenetriamine 10.0 pbw

The mixture was hand stirred, and then de-aired for 10 minutes at room temperature, and cast. The samples were cured @ 70°C for one hour. *Table VII* lists the electrical properties of this formulation.

In the meantime, this same 90° formulation was tested for thermal shock properties by cycling between −65° and 90°C according to the procedure outlined in MIL-I-16923B. The samples all passed the ten cycles required.

A formulation was made up replacing the ground limestone with T-60 alumina as follows: (RS8274)

Epon 820 100.0 pbw
T-60 Alumina 100.0 pbw

It was mixed, de-aired for 10 minutes, and cast onto ferro-type plates. In order to accelerate the cure the samples were put into an oven @ 70°C for one hour. The results of the electrical tests are noted in *Table VIII*.

For testing the behavior of methyl nadic anhydride cured systems, the following formulations were made up:

Table VIII. Electrical Properties of RS8274

Dielectric constant (60 cps)	5.4
Power factor (%, 60 cps)	2.2
Volume resistivity (500 VDC)	2.04×10^{13} ohm-cm
Dielectric strength (V/M)	563

Table IX. Properties of Three Methyl Nadic Anhydride Systems

	RS8275	RS8276	RS8273
Dielectric Constant	3.57	3.3	4.31
Power Factor (%)	0.33	0.28	0.31
Volume Resistivity (ohm-cm)	4.61×10^{15}	2.5×10^{16}	1.16×10^{16}
Pot Life, hrs.	8	8	12

RS8275	Ciba 6010	100.0
	methyl nadic anhydride	77.0
	DMP-30	3.0
RS8276	Epon 820	100.0
	MNA	77.0
	DMP-30	3.0
RS8277	Epon 820	100.0
	MNA	77.0
	DMP-30	2.0
RS8278	Epon 820	100.0
	MNA	77.0
	DMP-30	1.0

The formulation acceptable for the 130°C class was made as follows:

RS8273	Epon 820	100.0 pbw
	T-60 Alumina	100.0 pbw

The ingredients were hand mixed, ground one pass on the three-roll paint mill, and to the mix was added:

Methyl nadic anhydride 77.0 pbw
DMP-30 3.0 pbw

The blend was hand-mixed, and deaired for ten minutes, and cast.

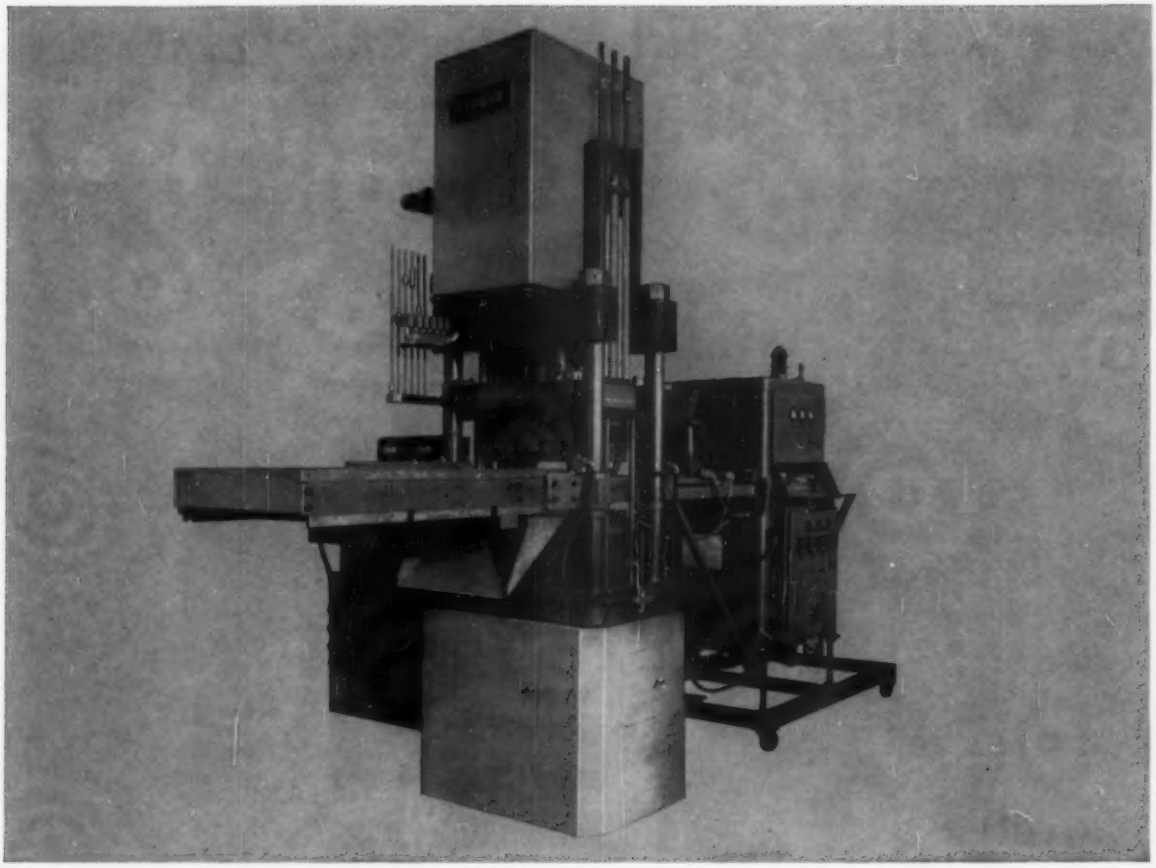
Table IX summarized the results of electrical tests run on several MNA systems.

Conclusions

By careful control of materials and regulations of processing conditions, low cost and high reactivity epoxy compounds can be utilized on the production line for encapsulating electronic components. The use of proportioning-metering equipment greatly extends the limits of applications of these compounds.

The materials thus formulated are shown to be quite adequate in properties for the required specifications.

A brief check of the important electrical properties of higher temperature system indicates the feasibility of readily developing formulations for performance over temperature ranges up to and including class H requirements.



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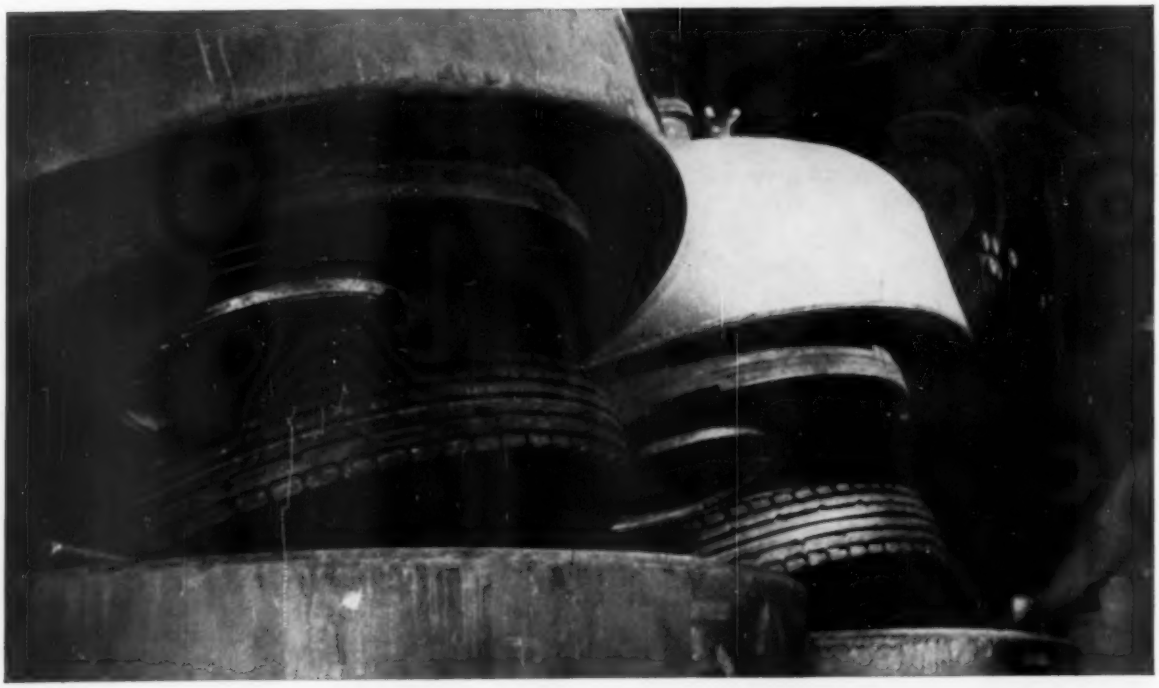

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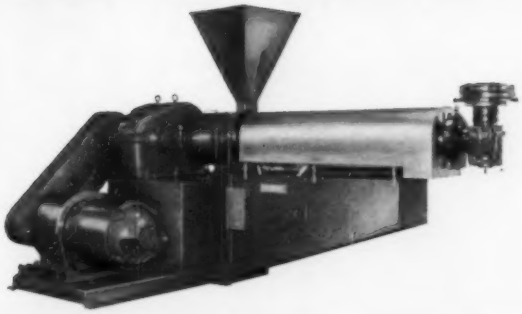

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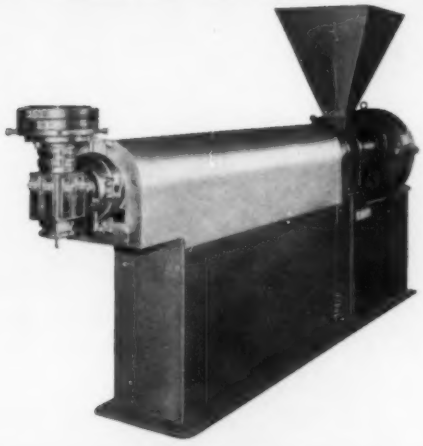

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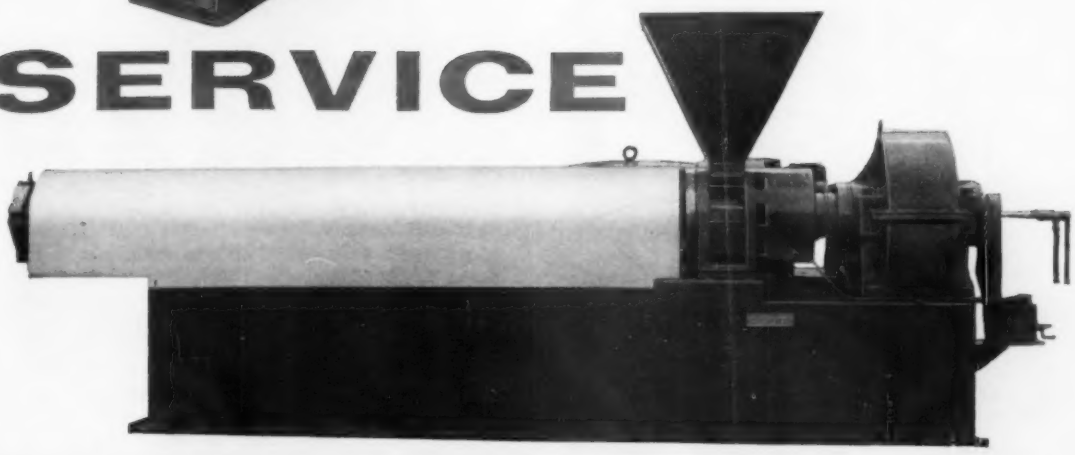

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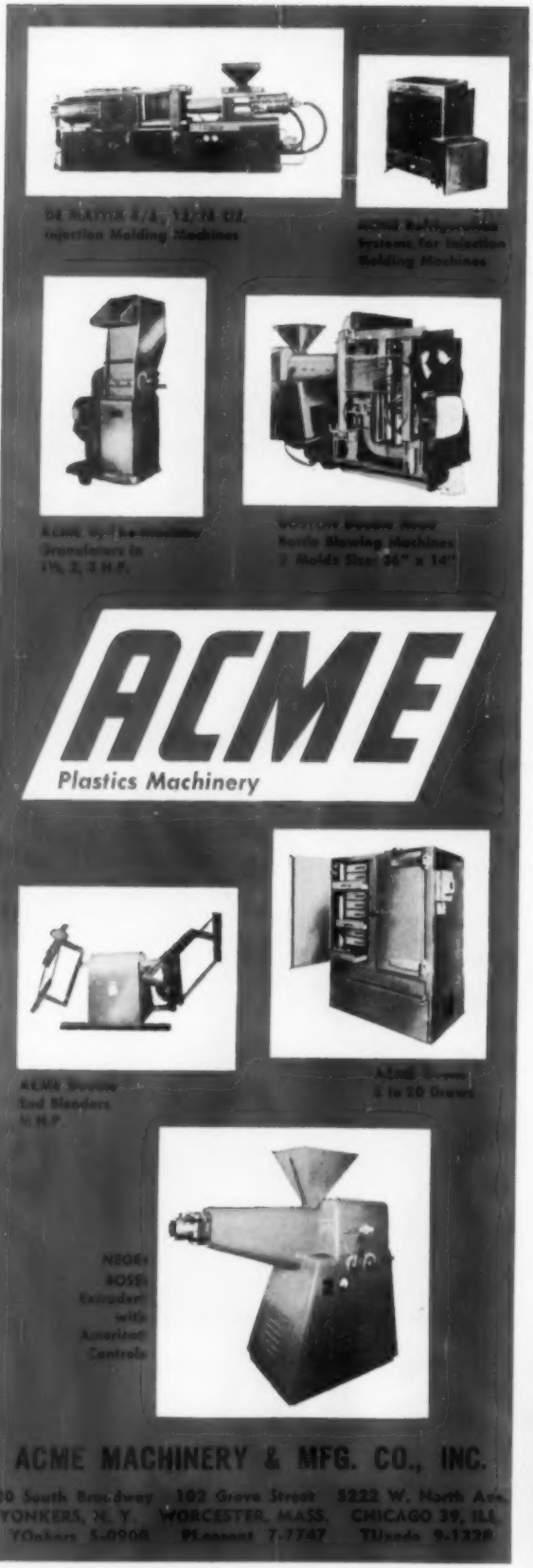
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Special Events

- **Tuesday—January 12, 12:00 Noon—Bel Air Room**
  Education Committee Luncheon

  Trends in Engineering Education as They Affect the Plastics Industry

  Speaker: Dr. Ralph A. Morgen, President, Rose Polytechnic Institute, Terre Haute, Ind.

  Tickets: $4.50 each, available at registration desk.

- **Wednesday—January 13, 12:00 Noon**
  Membership Luncheon—Boulevard Room

  SPE President Frederick C. Sutro Jr., in the Chair
  Introduction of 1960 Officers
  Annual Business Meeting of the Society
  Presentation of certificates to Distinguished Members and charters to new sections
  Tickets: $4.50 each, available at registration desk.

- **Thursday—January 14, 7:30 P.M.**
  Dinner-Dance—Grand Ballroom

  The Bob Kirk 15-piece Orchestra
  Hawaiian Airs Troupe
  Floor Show—9:00 to 10:30 P.M.
  Dancing 10:30 Till Midnight
  Tickets: $4.50 each, available at registration desk.

- **PAG's and Committee Meeting—page 106**

REGISTRATION INFORMATION

Monday, January 11, Writing Room, Ballroom Floor—Registration, open 1:00 P.M.

Tuesday Morning, January 12 until Firday noon, January 15, Ballroom Foyer—Registration open 8:00 A.M.

Registration Fees

SPE Member* **$15.00**

Non-Member **$30.00**

Student ..... **$ 5.00**

* Under a reciprocal agreement, SPI individual members admitted to ANTEC at SPE member rate

SPE MEETINGS during ANTEC

Meetings will be held at the Conrad Hilton Hotel, Chicago, Ill.

PROFESSIONAL ACTIVITIES GROUPS

The program of our 16th ANTEC, January 12-15, The Conrad Hilton, Chicago, has been built around SPE's Professional Activities Groups. To encourage every SPE member and guest attending ANTEC to participate in them, the period from 3:30 until 5:30 P.M. on January 12-14, inclusive, will be devoted exclusively to PAG meetings. Afternoon technical sessions will adjourn at 3:15 P.M.

PAG'S-Tuesday—January 12
Time for all meetings, 3:30-5:30 P.M.

PAG	Room
Polymer Structure & Properties	Grand Ballroom
Plastics in Buildings	1
Casting & Plastics Tooling	Waldorf
Finishing	2
Fabricating	Williford

Wednesday, January 13

Injection Molding	Williford
Vinyl Plastics	Grand Ballroom
Plastics in Electrical Insulation (Dinner for Plastics in Electrical Insulation—Room 4, 6:00 P.M.)	1
Extrusion	4
Reinforced Plastics	3

Thursday—January 14

Thermosetting Molding	Grand Ballroom
Standards for Reporting Properties	5
Metals for Plastics Molds	Waldorf
Forming	The Upper Tower

* Rooms 1 through 10 on 3rd Floor, 11 through 20, 4th Floor

ANTEC Committee Headquarters and Events

	Room
ANTEC Committee (Tues. thru Fri.)	9
Press Room (Mon. thru Fri.)	19
Ladies Hospitality (Tues. thru Thurs.)	Astoria Room
Moderators and Speakers Meals:	
Breakfasts (Tues. thru Fri. 8:00 A.M.)	4
Luncheons (Tues. thru Thurs. 12:00 P.M.)	4

COMMITTEES
Monday, January 11

Committee	Time	Room
Council	9:15 A.M.-5:30 P.M.	2
Council Luncheon	12:30 P.M.	Astoria
Editorial Advisory Board	7:30 P.M.-10:30 P.M.	1

Tuesday, January 12

Educational Exhibit Committee, Plastics in Building PAG	7:30 A.M.-9:00 A.M.	Park Lane Restaurant North Lobby
Meetings	2:00 P.M.-5:00 P.M.	10
Education	2:30 P.M.-6:00 P.M.	5
Technical Volumes	3:00 P.M.-4:00 P.M.	12
Publications	4:00 P.M.-6:00 P.M.	12

Wednesday, January 13

1960 Council	2:00 P.M.-4:00 P.M.	2
Membership (including Regional, Section, and Student Chm)	3:00 P.M.-6:00 P.M.	12
Inter-Society Relations	5:00 P.M.-7:00 P.M.	14
Section Presidents	8:00 P.M.-10:30 P.M.	12

Thursday, January 14

Past Presidents Advisory Board Meeting	10:00 A.M.-12:00 P.M.	3
Luncheon	12:00 P.M.- 2:30 P.M.	3

Friday, January 15

PAG Officers	10:00 A.M.-12:00 P.M.	19
Officers 16th and 17th ANTEC Executive Committees	12:00 P.M.- 2:00 P.M. (lunch)	3

COMPLETE

PROGRAM

AND

ABSTRACTS

Tuesday, January 12, 1960 • 9:00 to 11:15 A.M.
Concurrent Sessions—1 and 2

Session 1—Grand Ballroom
Polymer Structure

Moderator—Dr. Robert R. Stromberg *National Bureau of Standards*

1. **Calculation of Melting & Freezing Rates (Delrin Acetal Resin)**—P. N. Richardson, *E. I. duPont de Nemours & Co., Inc.*

Heat transfer rate calculations involving the melting or freezing of a crystalline plastic in the past have not been possible because of complex mathematical relationships. These arise because both latent heat or fusion and sensible heat must be taken into account. In other words, the heat capacity has a complex dependence on temperature. With the use of a high speed electronic computer these problems can be solved, and from such computer studies simple formula can be developed which allow one to calculate rates of melting and freezing using simple arithmetic.

Such a problem has been solved for the first time, and "Delrin" acetal resin was used as the example of crystalline plastic. The paper is concerned with the practical application of the simple formulas which resulted from a computer study. The following applications are discussed: Extrusion of rod, gate freeze-off time in injection molding, and the time required to reheat machines which are full of resin.

2. **Thermal & Shear Degradation of Polyethylene Melts**—H. Schott and W. S. Kaghan, *Olin Mathieson Chemical Corp.*

Most data published on the effect of shear on melts of different polymers indicate that a degradation takes place, resulting in decreased viscosity and molecular weight. Present work shows that molten polyethylene resists shear degradation under normal extrusion conditions.

A 4½" long capillary die attached to a screw extruder was used to subject polyethylene melts to shear. One sample of a commercial low density resin was extruded four times in succession at 400°F., and a sample of another commercial low density resin was extruded four times in succession at 504°F. The melts were quenched and repelletized directly after each extrusion. The pressure drop-flow rate relations of each resin before and after the four extrusions were the same, as were the intrinsic viscosities, indicating that no degradation had taken place.

Six successive extrusions of a commercial high density polyethylene resin at 325°F. did not change its melt or solution viscosity. At 525°F., slight increase in melt viscosity were observed after each of five successive extrusion passes.

3. **A Statistical Study of the Effect of Formulation Variables on the Properties of Sorbitol Polyether-Based Rigid Urethane Foam**—J. E. Wilson, H. M. Truax and M. A. Dunn, *Atlas Powder Co.*

Each rigid urethane foam formulation must be carefully designed to meet the key requirements of its specific end use. For example refrigerator insulation is an application which requires low thermal conductivity, low density, and excellent resistance to humid aging.

The present investigation was undertaken to provide information about the effect of the following factors on

foam properties: (1) Catalyst concentration–2 levels. (2) Isocyanate/hydroxyl ratio in quasi-prepolymer–2 levels. (3) Quasi-prepolymer preparation technique–2 levels. (4) Dispersing agent concentration–2 levels. (5) Isocyanate/hydroxyl ratio in total foam–4 levels.

Prior to carrying out the main investigation, a study was made of prepolymer preparation techniques to enable the selection of reasonable values for factors (2) and (3). A fractional factorial pattern of 32 foam formulations was then set up, and the data from all formulations were utilized in the interpretation of the effect of each factor. The significance of each observed effect was assessed by comparison with the random experimental variation, which was also computed from the data.

4. **The Effect of Molecular Weight Distribution on the Flow Properties of Polyethylene**—D. R. Mills, G. E. Moore and D. W. Pugh, *U. S. Industrial Chemicals Co.*

The melt flow properties of various polyethylenes under a wide range of shear stresses have been investigated. The effect of molecular weight distributions as found in blends, fractions and experimental polyethylenes is examined over this wide range of shear stresses. The resulting extrudates from the capillary rheometer used were examined for melt fracture and spiral formation.

The effect of die geometry on the extrudate roughness and inherent flow properties of the different polyethylenes show some dependence on fundamental polymer properties as well as the die geometry. As the molecular weight distribution increases for a given average molecular weight, the sensitivity of melt flow to pressure increases, and to temperature, decreases.

As the included entry angle of the die decreases, the surface roughness or melt fracture decreases. In the case of linear polyethylene, the extreme melt fracture observed with a die of 180° included angle practically disappears with a die of 40° included angle. The sharp break observed in linear flow curves was shifted but not erased by this change in die geometry.

Tuesday, January 12, 1960 • 9:00 to 11:15 A.M.

Session 2—Williford Room
Physical Properties

Moderator—Dr. Ed T. Severs, *AviSun Corp.*

5. **Relations Between Physical Properties & Molecular Structure of Polypropylenes**—N. H. Shearer, Jr., J. E. Guillet and H. W. Coover, Jr., *Tennessee Eastman Company*

The physical properties of a crystalline polyolefin are uniquely defined in terms of six features of its molecular structure. These are: average molecular weight, distribution of molecular weight, average degree of branching, distribution of branching, average degree of stereoregularity.

A study has been made of the changes in physical properties of polypropylene which can be induced by variations in these molecular structure parameters.

Injection-molded specimens respond somewhat differently than compression-molded specimens to changes in molecular characteristics. This difference is most noticeable in those pysical properties which are strongly dependent upon molecular weight, such as impact strength, tensile strength at break, and elongation.

The polypropylenes studied include the following types: a series of highly crystalline polypropylenes of increasing average molecular weights, blends of high- and low-molecular-weight polypropylenes, blends of amorphous and crystalline polypropylenes, and copolymers of propylene. The physical properties found in these different polypropylenes vary from the high degree of hardness, high softening points, and high degree of stiffness which characterize highly crystalline polypropylene to the lower softening point and higher impact properties associated with conventional polyethylene.

6. **The Measurement of Polyethylene Degradation by ZST Test**—T. H. Meltzer and John J. Muldrew, *Electric Storage Battery Co.*

The Zero Strength Time test provides a tool suitable for measuring oxidative alteration in polymers. Although not without limitations, ZST is generally more sensitive and covers a wider range of oxidative change in polyethylenes than does melt index.

This paper presents a comparison of the melt indices and ZST values obtained for a series of polyethylene resins incrementally oxidized by hot milling, and by exposure of fuming nitric acid. Specific viscosity measurements are presented as well. It is seen that while melt index more early reflects the onset of cross linking, ZST provides a more continuous record of the polymer's oxidative degration. The resins examined contain both high and low density types, and include polyethylenes with and without antioxidant. Finally parameters of the ZST test pertinent to its application as a diagnostic tool for polyethylene ageing are discussed.

7. **Environmental Stress Rupture of Polyethylene**—L. L. Lander, *Union Carbide Plastics Co.*

A new environmental stress cracking test using a constant stress principal has been developed. This test was developed because the present Bent Strip (or Bell Laboratories') test has been found to be unsuitable for high density polyethylenes. This procedure permits the determination of the life of a material exposed to corrosive environments at several combinations of stress levels and temperatures.

The environmental stress rupture behavior of several polyethylenes in Igepal have been determined. These materials range in density from 0.916 to 0.960 gm/cc and melt index from 0.2 to 20.0 dg/min. The behavior of these compounds have been investigated at several combinations of stress (from 1,400 psi to 300 psi) and temperatures (28°C, 40°C, and 60°C).

Illustrations are given of the effects of stress level, temperature, melt index, and density on the environmental stress rupture of polyethylenes.

8. **Working Stress Limits for Thermoplastic Structural Components**—W. D. Harris, *Dow Chemical Co.*; F. J. McGarry, *MIT* and W. W. Burlew, *Dow Chemical Co.*

Plastics are finding increasing uses in structural applications where quality and long-term endurance under stress are required. Plastic pipe and tubing for home cold water service and transport of chemical solutions, plastic table legs, refrigeration components, fish net floats, etc. are examples.

To get the best strength-to-weight ratio and to insure success in the use of a plastic material under load, it is essential that designers and engineers have a knowledge of the stress-strain-time-temperature relationships for the various plastics. The effective strength of a materials as a func-

tion of time and temperature differs markedly from that observed in short-time strength tests.

Simple and inexpensive but unique test methods and equipment have been developed to provide the design engineer with data relating strength to time-temperature, and environment so that he can quickly determine what the maximum allowable stresses in a component will be or conversely what the cross-sectional dimensions of the part must be to withstand a given stress.

Education Luncheon–

Tuesday, January 12
12:00 Noon

BEL-AIR ROOM **TICKETS $4.50**

Tuesday, January 12, 1960 • 1:30 to 3:10 P.M.
Concurrent Sessions–3, 4, and 5

Session 3—Grand Ballroom
Blow Molding

Moderator—G. S. Brown, *Plax Corporation*

9. **Extrusion Blow Molding Techniques for High Density Polyolefins**—Robert Doyle, D. E. Perry and T. E. Branscum, *Phillips Chemical Company*

This paper gives machine-side information on extrusion blow molding. Discussed are: Control cabinets, molding variables, mold temperature, blow pressure, and wall thickness.

10. **The Blow Molding of Cellulosic Plastics**—D. A. Jones and R. J. Haughwout, *Celanese Plastics Co.*

Paper reports laboratory findings in studying the extrusion blow molding of cellulose acetate and cellulose propionate. Cellulosic plastics can be worked very much like wood and soft metals in post finishing operations. The blown items can be buffed, punched, or drilled for the removal of excess material from pinched-off regions and the blowing air entrance.

11. **Blow Molding**—W. O. Bracken, *Hercules Powder Company*

A complete characterization of the blow molding industry–the markets, the locations, the machinery sales, the cost of equipment, the equipment makers, and the future.

Tuesday, January 12, 1960 • 1:30 to 3:10 P.M.

Session 4—Williford Room
Fabricating and Finishing

Moderator—Jerome Formo, *Minneapolis-Honeywell Regulator Co.*

12. **Post Molding Operations on Acetal Resins**—R. L. Miller, *E. I. duPont de Nemours & Co., Inc.*

Various operations which offer possible benefits of reduced cost, greater design flexibility, and improved appearance may be utilized in finishing a molded part. Delrin® acetal resin because of its good dimensional stability, high rigidity, and low moisture absorption is particularly well suited for post molding operations such as machining, welding, and mechanical joining.

Acetal resin is easily machined to close tolerances. Equipment an procedures are described for standard machine shop operations. In general, acetal resin is similar to free-cutting brass in machining characteristics. Burring may be minimized.

Thermal welding is readily applied to acetal resin. Joint configurations and assembly techniques for strong welds are discussed. Emphasis is placed upon high speed spin welding using new automatic tools. The fast setting rate of acetal resin is a distinct advantage in spin welding on fast cycles. Also disussed are hot plate, hot wire, hot gas, and induction welding.

13. **Vacuum Metallizing as Related to Plastics**—T. J. LaBounty, *Midwest Technical Service*

It is becoming more difficult to tell the difference between chrome plated steel and vacuum metallized plastics, unless you pick them up.

Vacuum metallizing a technique used in depositing aluminum on plastics, gives an appearance of chrome plate. Newly developed coatings, when used in conjunction with metallizing plastics are light weight, no corrosion problems, and lower costs.

Many automotive manufacturers have been taking advantage of this process in their new cars. Dome lights, instruments, bezels, and horn buttons are examples. Details of this technique will be given in the paper.

14. **Method for Determination of the Effect of Annealing on Residual Molding Stresses**—L. B. Allen, *International Business Machines Corporation*

A discussion of the applicability of brittle lacquer techniques in the metal fabricating field will be given, including some history of the method. The next portion will deal with experimental observations in the use of this method for evaluation of annealing efficiency. Actual photographs of parts, and experimental data will be included. Some discussion of the potential accuracy of the method will be included along with a sample calculation. It is important to note that this method indicates a time rate of decline of residual stress with annealing, and as such we are usually not interested in high accuracy, or absolute values. A general leveling off of the residual stress curve is usually noted and this is what is most important, rather than the actual value.

A brief description of the experimental procedure will follow, along with some necessary precautions for safety. The paper will conclude with a mention of other possible uses for brittle lacquer analysis.

Tuesday, January 12, 1960
1:30 to 3:10 P.M.

Session 5—Waldorf Room
Casting & Plastics Tooling

Moderator—Lawrence Wittman, *L. Wittman & Company*

SPE ANTEC

15. **A Heat Conductive Epoxy Formulation for Low Cost Molds**—R. T. O'Connor and H. J. White, *Devcon Plastic Steel Corp.*

Because of their unique properties, epoxy resins were chosen by Devcon Corporation as the basis for a material to make low-cost molds for plastics and rubber. A specially modified epoxy resin with a metallic filler was formulated and used with a combination of hardening agents to produce such a compound.

Preparation of the model, mixing the resin and hardener, and curing are the basic steps necessary to produce a cured epoxy casting, which can be used as a mold.

16. **Plastics Tooling for Plastics Production**—Frank L. Bogart, *Marblette Corp.*

Electrodes: The use of electrical discharge machines to produce a cavity for injection or compression molding has proved economical and otherwise advantageous. However, an improved method of producing electrodes for such machines has been developed by Dix Engineering, Detroit, for use in Elox equipment. A spray metal surface is combined with epoxy core backing to produce inexpensive yet accurate electrodes.

While successful use of plastic masters for hyrotel or duplicator machines has occurred for years, greater industry education is needed to bring about widespread adoption. Epoxy castings can be taken from original models whether these be made of plaster, wood, clay, or other materials. A plastic duplicate of an original can be taken from the plastic mold, holding tolerances of one or two thousands, with great labor savings over other means of producing duplicates.

Vacuum forming of sheet plastics can be accomplished on plastic forms as substantial savings when limited runs or prototype parts are needed. Inexpensive casting can be done to duplicate original models made of clay, plaster, soft wood, or other quickly worked materials.

17. **The Manufacture of Large Reinforced Plastic Molds for Hand Layup**—E. P. Weaver, *Atlantic Marine Industries, Inc.*

The manufacture of good serviceable large molds for hand layup molding is the result of careful planning and checking each stage of the operation. The basic operations are not difficult and several variations are possible. Knowing or determining your limitations in manpower, space, time, part requirements and other details mentioned in the paper will ultimately determine how the mold is to be made. Pitfalls can be avoided by developing as accurate a schedule as possible and going over them carefully with the responsible personnel before work has begun. Constant checking of these schedules and work as the job progresses will insure the meeting of predetermined limits of time, materials and quality. The paper shows the major operations involved, including some of the possible variations, describing within these operations those steps which are most necessary and critical to ultimate success. Careful selection of the methods to suit the mold to do the job and production capabilities can accrue considerable savings. The large plastic mold therefore should be designed and engineered just as carefully as the part to be produced.

Wednesday, January 13, 1960 • 9:00 to 11:15 A.M.
Concurrent Sessions—6, 7, 8, and 9

Session 6—Grand Ballroom
Injection Molding—I

Moderator—Bennett Nathanson, *Monsanto Chemical Company*

18. **The Effect of Orientation on the Physical Properties of Injection Moldings**—G. B. Jackson and R. L. Ballman, *Monsanto Chemical Company*

This paper presents results of tests designed to injection mold test specimens over a wide latitude of molding conditions chosen to give a maximum range in the degree of frozen-in orientation and to analyze mechanical properties of the moldings both parallel and transverse to the direction of flow.

19. **Design Considerations for Molded Polyolefin Items**—J. N. Scott, J. V. Smith and D. Alexander, *Phillips Chemical Company*

Paper covers broad mold design principals. For instance: Avoid large flat sections, use features that allow relief of minor stresses, and incorporate as much structural rigidity as possible.

20. **Insert Molding with High Density Polyethylene**—W. L. Price and W. A. Hunter, *Celanese Plastics Co.*

Improved stress cracking resistance may be obtained with insert molded parts by increasing wall thickness and by the elimination or reduction of thickness of the knurling. In actual practice, wall thickness of less than .125 inches are not recommended for use with insert molding of high density polyethylene.

21. **An Analysis of Injection Mold Filling of Polyethylene**—R. B. Staub, *Union Carbide Plastics Co.*

Under certain conditions, the complexities of mold filling can be simplified, and mold filling lends itself to analysis in terms of existing flow theory. This paper provides a simplified analysis of mold filling.

Wednesday, January 13, 1960 • 9:00 to 11:15 A.M.

Session 7—Williford Room
Extrusion—I

Moderator—George P. Kovach, *Foster-Grant Company*

22. **Pressure Development in Extruder Screws**—B. H. Maddock, *Union Carbide Plastics Co.*

Pressure is developed in the compression section of metering type screws as a result of compacting and fluxing in this area and may reach a peak value as high as 5000-8000 psi at the entrance to the metering section. This causes a forward pressure flow through the metering section, unless the die resistance is very high, and an output rate as much as 30-40% greater than the calculated pumping capacity of the metering section. Extrusion is thus controlled from a point somewhere in the transition section and this point is influenced by material properties and a number of screw design and operating variables. This paper describes experiments with screws of several L/D ratios and several types of materials, illustrating the effects of temperature, material viscosity and other factors on pressure profiles and product quality.

23. **Monofilament Tester**—J. P. Fogerty and J. J. Whidden, *W. R. Grace & Company*

This paper gives results of tests relating effects of extrusion and orienting conditions to tensile strength. It is shown that the most important factor affecting the tensile strength

of the mono-filament is the orientation ratio. The higher the orientation ratio, the higher the tensile strength, and these two factors are a straight line relationship.

24. **The Chill Roll Extrusion of Polypropylene Film**—G. C. Calderwood, *Spencer Chemical Company*

The end-user looks for package appearance, machinability and protective qualities in any film supplied to him by a processor. This paper will be mainly concerned with those properties of polypropylene film which can be affected by processing conditions.

General recommendations and observations on equipment design are made. The problem of surge in polypropylene film extrusion is discussed and methods of avoiding this problem are presented. This discussion will mention extruder L/D ratio, screw design, die temperature profile, screw rpm's and die gap.

A detailed analysis will be presented of those variables open to a processor with given equipment with the resultant effect upon polypropylene film properties. These variables, studied in a random balance statistical experiment at two levels each, will include screen pack, stock temperature, air gap, chill roll temperature, and take-off speed. The effect of these variables on impact strength (MD & TD), haze, gloss (MD & TD) and slip resistance will be presented.

25. **Rapid Response Recording of Extrudate Temperature and Pressure—Typical Use in Evaluating Extruder Performance**—H. B. Kessler, R.N. Bonner, C. F. W. Wolf and P. H. Squires, *E. I. du Pont de Nemours & Co., Inc.*

Reports on work done to combine strain gauge pressure transducers and unshielded thermocouples with rapid response recorders to provide more precise measurements of pressure variations of one p.s.i. and temperature variations of less than one degree F. in less than one second.

Wednesday, January 13, 1960 • 9:00 to 11:15 A.M.

Session 8—Waldorf Room
Reinforced Plastics

Moderator—Roger White, *Glastic Corporation*

26. **The Experimental Determination of Panel Shear Strength and Modulus of Rigidity for Glass Reinforced Plastic Laminates**—A. P. Penton, III, *Convair*

This paper is based on experimental work that Convair, Fort Worth Division, is doing on the determination of panel shear strength and modulus of rigidity of glass reinforced plastic laminates. The principal method discussed will be a picture frame loading device capable of producing approximately pure edgewise shearing forces in the plane of the laminate. The method of test preparation; specimen attachment and test set-up; will be given. The test procedure and method of shearing strain measurement will be given in detail. The methods of analysis of the data obtained to calculate panel shear strength and modulus of rigidity will be explained. This will be supplemented by some basic theory of the behavior of glass reinforced plastic laminates with respect to shearing stresses. The above items will be illustrated by data, sample calculations, and results which were obtained by this test method.

27. **Heat Resistant Reinforced Plastic Laminate**—John Miglarese, *Westinghouse Electric Corp.*

Highlights from the paper:

(a) A theory as to the cause of delamination and blistering of a phenolic laminate during postcure.
(b) Physical and electrical properties of Micarta Grade H-5834, a high temperature resistant phenolic glass reinforced laminate with a long cycle postcure.
(c) The flexural strengths of Micarta Grade H-5834 at various temperatures with curves are presented.
(d) A comparison of properties at room temperature and elevated temperatures of glass, leached glass and quartz reinforced laminates.
(e) Erosion rates, as produced by an oxy acetylene torch, are recorded on phenolic and other resin laminates.
(f) Thermal degradation losses of several resins measured in air and in nitrogen are presented.

28. **Polyester Resin Evaluation for Long-Term Wet Strength Retention**—C. E. Loetel and H. E. Fordyce, *The Marley Co.*

To design structural parts of glass fiber reinforced polyester subject to water immersion requires data on their wet strength retention. Previously published data on long-term immersion either did not record strength retention or the tests were not of sufficient duration to be convincing.

Accelerated tests of polyester at 10 psi steam, 200°F and 160°F water immersion have been carried out. The results have shown that only a few of the polyester resins presently available will retain adequate strength in water immersion applications.

Correlation of the results of tests at 10 psi steam and 200°F hot water has been made. At 160°F strength is lost much more slowly. But results are indicative of the original resin strength and the way it was catalyzed.

Catalyst systems were explored briefly. A combination of catalysts gave the best results in some of the resins. In others this was not a significant factor.

29. **High Temperature Epoxy Resin Laminates**—R. O. Menard, W. W. Cooner, *E. I. du Pont de Nemours & Co., Inc.*

Pyromellitic dianhydride (PMDA) is a versatile curing agent which imparts outstanding thermal resistance to cured epoxy resins. New techniques have been developed for preparing PMDA-cured laminates which have excellent high-temperature strength after exposure at 500°F. for more than 500 hours. DRY LAY-UP—Glass fabric-reinforced laminates based on a conventional epoxy resin and a PMDA-glycol reaction product had flexural strengths of 35,000 psi at 500°F. after 500 hours exposure WET LAY-UP—PMDA of extremely fine particle size (98% less than 10 microns) was dispersed readily in liquid epoxy resins, and laminates with a good balance of properties were prepared. These showed essentially no change in strength during 500 hours exposure at 500°F. LOW-TEMPERATURE CURE—A formulation was developed which required a cure of only one hour at 250°F. and no post-cure to achieve substantial strength at 500°F. Heat aging at 500°F. improved the flexural strength considerably.

Wednesday, January 13, 1960 • 9:00 to 11:15 A.M.

Session 9—Room 2
Standards for Reporting Properties and Thermosetting Molding

Moderator—Elias G. Greninger, *The Bryant Electric Company*

30. **Melt Index Equivalent—A New Flow Parameter**—P. J. Boeke, R. J. Martinovich, R. A. McCord, *Phillips Chemical Company*

In the past, melt index has been employed as a means of characterizing the performance limits of polyethylene resins. Recently, studies have also been carried out on various high shear viscometers to supply similar data. Results have been obtained and will be presented which indicate that although either of these measurements are useful in characterizing resins made under essentially the same conditions, *they lose their significance as a measure of performance when applied* to resins made under different processing conditions. A new method is proposed for characterizing polymers which can be applied to any polyethylene resin regardless of manufacturing conditions employed. This method consists of determining the grams of polymer extruded in 10 minutes through a standard CIL high shear Viscometer orifice under a pressure of 1500 psi and a temperature of 190°C.

31. **Effects of Thermal History on Some Properties of Polyethylene**—J. B. Howard, Wm. M. Martin, *Bell Telephone Laboratories, Inc.*

Prior thermal history is shown to exert a strong influence on the values obtained in tests for such crystallinity-sensitive properties as density, low-temperature brittleness, and environmental stress-cracking.

Typical test results are reported for two ASTM Type I polyethylenes and a polyethylene-butyl rubber ocean cable insulating compound. The tests considered include density per ASTM Designation D-1505-57T, environmental stress-cracking per ASTM Designation D-1693-59T, and low temperature brittleness per ASTM Designation D-746-57T, the last using the standard specimen, the CIL notched modification, and the smaller ICI ABSNAC specimen.

Comparison of normally molded specimens with others from the same lots of material conditioned by the procedure of Birks and Rudin indicates that in general the latter give more reproducible extremes of values, the former a scatter of intermediate values. Much of the lack of agreement in inter-laboratory testing is presumably accountable on this basis.

32. **Preform Hardness vs. R. F. Preheat Time and Temperature of Phenolic Molding Materials**—E. W. Vaill, *Union Carbide Plastics Co.*

Preform hardness of phenolic molding materials has a major effect on the ratio frequency preheat characteristics of phenolic molding materials.

Measurement of the preform hardness with a Durometer "D" scale tester is a simple and accurate method of controlling preform hardness, once the optimum hardness rating has been established for a given material and preform size.

Controlled preform hardness and uniform maximum preform temperature are essential to present day high production requirements of phenolic molded parts produced by both the compression and plunger or closed mold methods.

At the present time, there is no generally accepted or widely used method of measuring accurately preform hardness. This paper will correlate in chart and graph from the the Durometer hardness of preforms of phenolic molding materials with radio frequency preheat time and temperature for the following types of materials: general purpose woodflour filled, medium impact cotton flock filled, and heat resistant mineral filled phenolic compounds.

33. **Cure of Molded Melamine Resin and Its Significance for Properties**—H. P. Wohnsiedler, R. A. Tiley, *American Cyanamid Company*

With the rapid growth of melamine molding compound in the dinnerware field, it is particularly important at this stage to consider certain basic properties of the material.

This paper explores a number of properties important to the durability of the plastic and how these properties are likely to change with design. Mechanical properties such as flexural and impact strength, thermal properties including deflection temperature under load and thermal shock and dimensional stability all vary to a greater or less extent with cure. Design of the part invariably incorporates different thicknesses. Since the time required to reach the cured state varies with thickness this is akin to introducing a non-uniform state of cure into the molded piece. Of the properties which vary with cure, shrinkage is apt to cause the most trouble. The resulting localized stresses can lead to failure by cracking. In the design of a mold, adequate attention should be paid to the problem of obtaining uniform cure throughout the molded piece.

Membership Luncheon–

Wednesday, January 13

12:00 Noon

BOULEVARD ROOM **TICKETS $4.50**

featuring

- ***Introduction of SPE's 1960 Officers***
- ***Annual Business Meeting of the Society***
- ***Presentation of certificate to Distinguished Members and Charters to New Sections***

PRESIDENT FRED C. SUTRO JR., IN THE CHAIR

Wednesday, January 13, 1960 • 1:30 to 3:10 P.M.
Concurrent Sessions–10, 11, and 12

Session 10—Waldorf Room
Plastics in Electrical Insulation

Moderator—Walter A. Gammel, Sr., *Automatic Process Control*

34. **Effect of Humidity on Surface Resistance of Filled Epoxy Resins**—L. S. Buchoff, C. H. Botjer, *Electro-Tec Corporation*

It was found early in the investigation that a close control of temperature and humidity were necessary to obtain reproducible results. Samples were humidified in jars containing sulphuric acid-water solution or glycerin-water solution in a chamber held to plus and minus 0.1°C.

Unfilled epoxies cured with an aromatic hardener have the highest resistance in humidity, i.e., 10^{13} ohms at 95% RH conditioning they returned to maximum readings in less than five minutes at 50% RH. Laminates took a little longer to return, and the filled epoxies needed additional baking to be brought up. Those containing calcium carbonate showed the lowest resistance of any filled plastic. Silica

filler gave somewhat higher resistances and Mica was the best of the three.

Epoxies cured with aliphatic polyamines and those cured with acid anhydride was inferior to the aromatic amine cured epoxies.

35. **Modified Alkyd Molding Compounds**—J. J. Moylan, P. D. Sullivan, *Allied Chemical Corporation*

This paper describes the new properties of alkyd-type molding compounds which have been possible through the use of these improved resins. These new compounds exhibit the desirable molding properties of the alkyds together with exceptional retention of insulation resistance under high humidity and elevated temperature conditions, their performance in this respect generally matching the diallyl phthalates.

36. **Low Loss Casting Resins**—William R. Cuming, *Emerson & Cuming, Inc.*

For certain critical electrical and electronic applications, it is imperative that casting resins used have low dielectric constant and low dissipation factor. Light weight and high temperature capability are also desirable. Epoxies, polyesters and other commonly used resins fall far short. There are several materials which do meet the low loss requirements. They include styrene, divinyl benzene, vinyl toluene, polybutadiene and various copolymers of these resins. Some compositions have temperature capability in excess of 500°F. Low loss and low weight fillers can also be used to further modify properties. Techniques have been developed to perform bulk polymerizations of these resins so that delicate electronic components can be embedded. Rod and sheet stock can also be made. Case histories and properties in comparison to other commonly used casting resins are presented.

Wednesday, January 13, 1960 • 1:30 to 3:10 P.M.

Session 11—Williford Room
Packaging

Moderator—J. R. Akers, *Union Carbide Plastics Co.*

37. **A New Test for Polyethlene Printability—The Inclining Platform Tester**—T. F. McLaughlin, Jr., *E. I. du Pont de Nemours & Co., Inc.*

This paper describes a new technique and the equipment for measuring the printability of polyethylene surfaces. The method offers accuracy and speed not found in previous methods. Measurements are made on a special instrument of the angles of inclination at which uniform drops of distilled water slide from treated surfaces. These angles are found to correlate with the printability of the surfaces.

38. **Design and Production Considerations for Thin Wall Formed Containers**—J. R. Lynch, *Dow Chemical Co.*

Vacuum formed hot drink cups, cottage cheese tubs, and other single use containers which are mechanically dispensed or filled and capped automatically are discussed in this paper. The effect of distribution of material on weight of the parts and design possibilities with respect to fabrication requirements are described. Structural members, and trimming and stacking methods are also included.

39. **Machine Design, Adaptations and Problems of Poly Film Overwrap Machines**—Boyd Redner, Jr., *Battle Creek Packaging Machines, Inc.*

The equipment characteristics peculiar to overwrapping which separate it from bag making, form, fill and seal, film sealing equipment, and the like will be discussed. The distinctive features of overwrapping equipment which make it different from that used in "flexible packaging" will also be delineated. The manner in which film gauge control, slip additives, rewinding techniques, etc., affect the film's operation on the overwrap machine will be developed.

The factors which influence the selection of a given film for overwrapping will be indicated. Here, the considerations felt necessary by a machinery manufacturer for selection of the film will be pointed out, showing how film characteristics and package requirements influence the selection of the packaging equipment. Conversely, the requirements that the selected film imposes on the machine and the item to be overwrapped will be discussed.

Wednesday, January 13, 1960 • 1:30 to 3:10 P.M.

Session 12—Grand Ballroom
Vinyl Plastics—I

Moderator—Robert Bostwick, *Union Carbide Plastics Co.*

40. **The Mechanism of Poly (Vinyl Chloride) Stabilization by Barium, Cadmium, and Zinc Carboxylates**—A. H. Frye and R. W. Horst, *The Carlisle Chemical Works*

Deterioration of poly (vinyl chloride) is due primarily to a zipper-like elimination of hydrogen chloride from the polymer giving rise to colored and easily oxidizable polyene structures. Baum and Wartman [*J. Polymer Sci.*, 28, 537 *(1958)*] have shown that elimination is initiated by the rupture of certain especially labile carbon-chloride bonds. It is known that the stability of poly(vinyl chloride) can be markedly enhanced by the incorporation of various additives, among which are the barium, cadmium, and zinc salts of certain carboxylic acids.

In Part I of this series [Alfred H. Frye and Raymond W. Horst, *J. Polymer Sci.*, in press] we reported on our infrared studies of poly(vinyl chloride) films containing and not containing the barium, cadmium, and zinc salts of 2-ethylhexanoic acid. On the basis of these studies we proposed that the stabilizing action of these salts is due at least in part to esterifying displacements of labile chlorine atoms by the carboxylate moiety.

We have now obtained independent and corroboratory evidence in support of the proposed esterifying displacements by studying the retention of radioactivity by poly (vinyl chloride) into which has been incorporated by milling, quantities of either the barium, cadmium, or zinc salts of 2-ethylhexanoic-1-C^{14} acid and thereafter subjected to repeated dissolution in tetrahydrofuran and precipitation by methanol. We have found that the extent of retained radioactivity varies with the duration and temperature of heat treatment of the milled poly(vinyl chloride)–metal carboxylate films, and parallels the intensities of the 5.75 u band reported in our infrared studies *(loc. cit.)*.

Taken together, the radioactivity studies and the infrared studies provide unequivocal evidence for the occurrence of the proposed esterification. Other experiments to be reported provide evidence that such esterification does indeed enhance the stability of poly(vinyl chloride) under the con-

ditions in which these metal carboxylates are employed in commercial practice.

41. **Color Stability of Vinyl Compounds Pigmented with Iron Oxides**—A. K. Woernle, *C. K. Williams & Company*

Elevated temperature tests of iron oxide-vinyl plastic composition show that excellent color stability may be achieved with proper selection of commercial grade compounding ingredients. A variety of types and shades of iron oxides and a variety of stabilizers were successfully used. Variations of fillers and plasticizers were also evaluated.

42. **The Food Additive Amendment and Packaging Material**—A. J. Lehman, *Food & Drug Adm. U. S. Department of Health, Education & Welfare*

Every manufacturer of packaging materials should be concerned with three main areas: Usage, composition, and extractability. Paper also cover filing of a petition establishing the safety of a substance intended for specific packaging applications.

43. **Poly (Vinyl Chloride) Adhesion to Synthetic Fabric**—C. F. Blaich, Jr., A. J. Sampson, *The Carwin Company*

The use of vinyl coated synthetic fabric in many applications has been limited by poor adhesion between the vinyl plastisol on sheet monofilament fabric. Although many improvements in adhesion have been made, the adhesion obtained is insufficient for many applications.

A system using Dianisidine Diisocyanate and Vinylite VMCH-3 or Geon 400X110 which gives high levels of adhesion between vinyl plastisol or sheeting and nylon, Dacron, rayon, or glass fabric has been developed. The adhesion is surprisingly independent of fabric construction and can be obtained over a wide range of operating conditions.

The paper gives the suggested composition of the adhesive primer and discusses the effects of varying the plasticizer concentrations in the primer and the types and amounts of solvents which can be used.

Thursday, January 14, 1960 • 9:00 to 11:15 A.M.
Concurrent Sessions—13, 14, 15, and 16

Session 13—Grand Ballroom
Injection Molding—II

Moderator—Bennett Nathanson, *Monsanto Chemical Company*

44. **Some Causes and Cures of Splash Defects in Acrylic Molding**—S. E. Giragosian, G. G. Freygang, *Rohm & Haas Co.*

Three different causes of splash defect are discussed. These are: Air splash, splash from thermal decomposition, and moisture splash. Effective remedies are given.

45. **Factors Affecting Toughness, Serviceability of High-Density Polyethylene Items**—J. N. Scott, D. Jones, P. J. Boeke, *Phillips Chemical Company*

This paper presents results of a comprehensive study illustrating the importance of correct molding practices. Items covered: Mold temperature, cylinder temperature, and thickness of gate.

46. **The Effect of Molding Conditions on Physical Properties of Polyethylene**—W. A. Dunlap, P. J. Meeks, W. T. Wickham, *Dow Chemical Co.*

This paper presents a study of part failure due to dominant internal or molded-in stresses in polyethylene.

47. **Flow of "Escon" Polypropylene in Injection Molding**—W. E. Heumann, *Enjay Co.*

One of the most important molding properties of any resin is its relative ease of processing or moldability (flowability). In this paper, flow data on a low melt index and several high melt index polypropylenes are compared to flow data for a conventional low density polyethylene, a linear high density polyethylene and two other commercially available polypropylenes. Table I shows physical properties for these polymers.

Thursday, January 14, 1960 • 9:00 to 11:15 A.M.

Session 14—Waldorf Room
Extrusion—II

Moderator—Don Williams, former President, *Chippewa Plastics*, currently consultant to the plastics industry

48. **Extrusion: Described by Experimentally Determined Equations**—H. J. Donald, J. K. Rieke, E. S. Humes, *Dow Chemical Co.*

A summary of some of the experimental work which has been designed to determine methods for describing extruder design and its relation to the flow properties of polymers. In particular the work reported attempts to relate equation of the type previously obtained to plasticizing extruders, and an effort was made to separate out the various effects of the feed, compression, and melt zones on the output.

49. **Techniques in the Extrusion of High Density Polyethylene Tubing and Profiles**—D. J. Schmidt, *W. R. Grace & Co.*

This paper gives information for selecting proper die design, cooling methods, and establishing optimum extrusion conditions. Major emphasis is placed on the post-handling and take-off techniques.

50. **Flow Patterns in a Single-Screw Extruder**—W. D. Mohr, P. H. Squires, F. C. Starr, *E. I. du Pont de Nemours & Co., Inc.*

This paper describes flow pattern of the viscous fluid in the channels of the screw. Photographs show that no fluid in the channel ever moves toward the rear of the extruder, so long as there is a net output from the extruder.

51. **Sucrose Acetate Isobutyrate in Cellulose Acetate Extrusions**—E. W. Wilson, Wm. M. Gearhart, *Eastman Chemical Products, Inc.*

Sucrose acetate isobutyrate has been found to be compatible with cellulose acetate and to impart some unique properties to such plastics, among those improved permanence, increased surface hardness and certain improvements in deep-drawing characteristics.

The effects of incorporating SAIB into cellulose acetate with dimethyl and diethyl phthalates will be shown. It will be shown that the use of triphenyl phosphate can be advantageous in certain formulations.

Examples will be given showing the use of this new material in cellulose acetate applications.

Thursday, January 14, 1960 • 9:00 to 11:15 A.M.

Session 15—Upper Tower
New Materials—I

Moderator—Dr. Clayton J. Ammondson, *Continental Can Co., Inc.*

52. **Properties of Intermediate Density Copolymers of Ethylene**—S. P. Foster, E. T. Pieski, S. H. Jenkins, Jr., *E. I. duPont de Nemours & Co., Inc.*

Polyethylene is indeed a versatile plastic. Many of the physical properties which have lead to its widespread use improve with increasing crystallinity. In the case of the currently used polyethylenes, there is unfortunately an optimum crystallinity level above which impact toughness and some of the time dependent strength properties (e.g., environmental stress crack resistance) become intolerably low for many applications. The intermediate density (0.93 to 0.94) copolymers of ethylene represent a real breakthrough with respect to raising this level of maximum allowable crystallinity. The effects of varying the density and the molecular weight of these new ethylene copolymers on such properties as environmental stress crack resistance, impact toughness, stiffness, heat resistance, stress-strain behavior, abrasion resistance and processing characteristics are discussed.

53. **Knowing and Recognizing Quality in Fabricated Teflon**—P. E. Thomas, *E. I. du Pont de Nemours & Co., Inc.*

In the years 1950-1957 the growth of new methods of fabricating TFE-fluorocarbon resins outstripped knowledge on control tests and specifications needed to define consistently high quality products. During the past several years the tide has been turned and a number of new test procedures and specifications established by trade and technical groups.

This paper describes the results of some of the studies that aided this effort and shows how a greater insight has been gained on the effects of basic characteristics such as per cent crystallinity and porosity level on properties and appearance. From an analysis of the significance of these and other basic variables, suggestions are given as to tests to permit positive identification of the quality of fabricated products. While emphasis is placed on practical mechanical tests and visual examinations, new instrumental methods are disclosed as laboratory tools for measuring percentage crystallinity and void content.

To inform end users as to the similarities and differences between TFE-fluorocarbon resins and the new copolymer FEP-fluorocarbon resins, comparative properties are reviewed. Simple tests are suggested which can be used as an aid in specifying the quality of injection molded or extruded FEP.

54. **Ethylene Copolymers**—P. J. Boeke, R. J. Martinovich, J. E. Pritchard, *Phillips Chemical Company*

The latest additions to the growing polyolefin family are the ethylene copolymers. Made in the Phillips process by copolymerization with 1-butene, these resins are characterized by a density of 0.95. In this paper the general physical properties of these interesting new copolymers are reviewed with particular emphasis on those properties affected by the lower density.

In general, the copolymer resins possess two important characteristics. They are exceptional resistance to stress cracking and excellent long term load bearing ability. These properties are possessed to a high degree in the low melt index extrusion grade resins. Data are presented showing the stress crack resistance and stress life of these copolymer resins as compared to the high density (0.96) homopolymer resins. In addition, information is presented showing those properties which make these resins especially suitable for large volume application.

55. **Polypropylene Wax—A New Resin for Plastic and Coating Applications**—J. E. Guillet, H. W. Coover, Jr., *Tennessee Eastman Company*

Recent developments in the field of olefin polymerization have made possible the synthesis of entirely new types of hydrocarbon waxes. The properties and some applications of the first of these new materials, polypropylene wax, is described in this paper.

The unique properties of polypropylene wax result from its very high crystallinity, which is in turn due to the stereoregular sequences of propylene units in the polymer molecule. As a result of this high crystallinity, polypropylene wax exhibits outstanding hardness and very high melting point. In the crystalline form, polypropylene wax has hardness superior to that of any available linear hydrocarbon wax and is quite brittle. However, it can be quenched to give products of lower average crystallinity which are unusually tough.

Polypropylene waxes can be manufactured in a wide range of molecular weights, varying from products with melt viscosities comparable to that of paraffin wax to those with viscosities approaching that high-melt-index polyethylene.

Thursday, January 14, 1960 • 9:00 to 11:15 A.M.

Session 16—Lower Tower
Vinyl Plastics—II

Moderator—Walter Waychoff, *Monsanto Chemical Company*

56. **Characterization of Poly (Vinyl Chloride) Resins by the Conductivity of Solvent Extract**—J. B. DeCoste, B. A. Stiratelli, *Bell Telephone Labs, B. F. Goodrich Chemical Co.*

A new method of distinguishing between electrical and non-electrical grades of poly(vinyl chloride) resins prior to compounding has been developed. A need for such a method has existed for some time because the customary procedure of compounding slabs for the determination of electrical properties is slow, costly and introduces compositional variables. The new method depends upon electrolytic conductivity measurements on an extract of the powdered resins. Only conventional equipment available in most analytical laboratories is required for performing the test. This approach assumes the soluble ionic impurities are the predominant factor in determining the electrical properties of the resin.

57. **The Use of Ditridecyl Phthalate in Poly(vinyl Chloride) Formulations**—W. A. Dimler, J. A. Mountain, W. F. Overberger, *Enjay Co.*

This paper describes a new oxo alcohol—tridecyl alcohol. It has found application in the vinyl plastic industry. The phthalate ester of tridecyl alcohol-ditridecyl phthalate (DTDP)—possesses a high boiling point (286°C./3.5mm Hg.) and has very low volatility characteristics when compounded with PVC. Applications will be in PVC film and sheeting and in PVC plastisols.

58. **Determination of Plasticizer Compatibility by Swelling Measurements**—A. C. Hecker, N. L. Perry, *Argus Chemical Co.*

In the course of work, it was found that rigid PVC immersed in pure plasticizer at room temperature showed no plasticized absorption whatsoever after two years of continuous immersion. Rapid absorption of plasticizer occurred at 76°C to an equilibrium quantity, with the extent of swelling plasticizer dependent. Incorporation of incremental amounts of plasticizer into PVC by milling showed that there was a critical concentration of plasticizer which had to be present before further swelling could occur at room temperature. This critical plasticizer content varies for different plasticizers.

The amount of a test plasticizer absorbed by a vinyl sheet, into which has been milled 50 phr of dioctyl phthalate, is a measure of the test plasticizer's compatibility with PVC. Equilibrium swelling data and rate of plasticizer pickup has been determined for more than 30 commonly used plasticizers and mixtures thereof. A procedure for determining potential compatibility of plasticizer mixtures by swelling measurements is proposed.

59. **Acrylic Polymers for Use in Rigid and Semi-Rigid Vinyl Compounds**—R. P. Hopkins, *Rohm & Haas Co.*

This paper discusses a recent commercial development in vinyl resin technology in which basic modifications of vinyl chloride homopolymers and copolymers are achieved by admixture with acrylic polymers.

The principal effects of such modification depend on the particular acrylic polymer employed. One type, for example, causes a favorable change in the classic flat temperature/softening curve of vinyl chloride homopolymer, with attendant pronounced improvements in workability at processing temperature but without detraction from mechanical properties at service temperatures. A second principal type of acrylic polymer is shown to produce exceptionally high notched impact strength in rigid vinyl compounds. Additionally, this type of modifier is shown to make possible the use of ordinarily unsatisfactory low "embrittling" concentrations of plasticizer in the production of semi-rigid vinyl plastics which exhibit a high degree of hardness, high impact strength and excellent heat stability. Data are also presented which indicate the utility of such an acrylic modifier for the improvement of properties of moderately plasticized vinyl formulations, particularly at low temperatures.

Thursday, January 14, 1960 • 1:30 to 3:10 P.M.
Concurrent Sessions—17, 18, and 19

Session 17—Grand Ballroom
Mold Design

Moderator—John Andras, *General American Transportation Corp.*

60. **Precision Geometrical Blending in Molds for Plastic Parts**—W. D. Evans, *Estee Mold and Die, Inc.*

By geometrical blending, unique things can be accomplished in the molding process, for example a controlled variable wall thickness economically produced. Other uses for blends in parts are: Uniform distribution of structural stresses from one part element to another, reduction of fatigue failure, reduction of internal casting stresses, and smoother surfaces on molded items.

61. **Thermal Consideration in Mold Design**—W. J. Stokes, *Stokes-Trenton Inc.*

This paper takes a look at present day problems in the design of molds and presses where heat control is a factor, and discusses some of the possible approaches to the solution of these problems.

62. **Mold Design for Improved Cycling**—R. L. Beesley, L. W. Meyer, J. W. Mighton, *Dow Chemical Co.*

Six ideas for improving injection molding cycle time are presented—a few of them have been used commercially, several are under study, the remainder are design concepts on paper only.

Thursday, January 14, 1960 • 1:30 to 3:10 P.M.

Session 18—Upper Tower
Forming

Moderator—D. P. Meiklejohn, *Monsanto Chemical Co.*

63. **Designing Thermoforming Molds for Linear Polyethylenes**—R. Doyle, D. E. Allison, *Phillips Chemical Company*

This paper gives guidelines for constructing molds for thermoforming linear polyethylene. Best molds will have the following properties: Constructed of aluminum for best heat transfer, channeled for efficient temperature control, and will have a moat for good vacuum seal.

64. **Summary of Thermoforming Techniques**—R. E. Kostur, *Comet Industries*

A review of various techniques and operations in the thermoforming of plastics materials.

65. **Requirements, Properties & Testing of Extruded High Impact Polystyrene Sheets**—R. George Hochschild, *Koppers Co., Inc.*

Seven laboratory tests are proposed for establishing standards and specifications of the physical properties of high impact polystyrene extruded sheets. Results of these tests will characterize the sheet material and will yield sufficient information to the material supplier, the fabricator, and the appliance manufacturer to enable them to plan further action.

Thursday, January 14, 1960 • 1:30 to 3:10 P.M.

Session 19—Waldorf Room
Foams

Moderator—Charles B. Sias, *Pittsburgh Plate Glass Co.*

66. **Controlled Density Polystyrene Foam Extrusion**—F. H. Collins, *Dow Chemical Co.*

Polystyrene sheet in a range of density from four to fifty pounds per cubic foot has been extruded in conventional extrusion equipment by adding polystyrene foam beads to various polystyrene formulations prior to extrusion. The materials, equipment, and fabrication techniques are described in this paper. Means for density control are shown. Lamination of the foamed sheet to other materials, and vacuum forming are included in the paper. Utilization of trimmings is also described.

67. **The Use of Extenders in Flexible Urethane Foams**—T. E. Ferrigno, *Minerals & Chemicals Corp. of America*

The term "extender" is used here rather than filler since this study revealed that either one-shot or prepolymer flexible urethane foams can be extended in foam volume by the proper choice and concentration of certain materials. Particularly advantageous are the aluminum silicates (kaolinite) and magnesium aluminum silicates (attapulgite). Surfation (surface modification) improves the compression set values obtained with aluminum silicate extended foams. The attapulgite, however, is extremely reactive with the isocyanate group, but surfation controls this condition thus making it a very useful extender.

In the polyether systems studied it was found that proper selection of extenders make it possible to achieve substantial cost reduction, increase or decrease in deflection values, improved compression set, better foam uniformity, and mixtures containing extender which are stable for several days before foaming.

Data is also given on the use of several unusual filler type materials which provide novel properties.

68. **Recent Developments in Rigid Polyurethane Foams**—L. R. LeBras, *Pittsburgh Plate Glass Co.*

A significant decrease in the thermal conductivity of rigid urethane foams by the use of halogenated hydrocarbon blowing agents is described. The insulation efficiency of the new foams are shown to be far superior to any of the conventional insulating materials that are presently being used. A brief review of some of the earlier work in the urethane field leading up to this development is reported. The properties of polyester based urethane foams blown with carbon dioxide and halogenated hydrocarbons are compared. In addition to much lower k-factor, the latter foams have lower moisture vapor transmission and lower exotherm characteristics. Data illustrating the retention of the blowing agent in urethane rigid foams by means of accelerated aging curves are shown. The results of these studies indicate a long range service from low k-factor foams. Some of the variables affecting k-factor retention are discussed. They are: foam density, cell structure, free blow versus restricted expansion, resin type and foam formulation. The use of lower cost polyether resins in rigid urethane foams blown with halogenated hydrocarbons is described. Properties of foams based on polyethers are presented. A comparison of typical polyether foam properties is made with typical polyester foam properties. One-shot versus semi-prepolymer foaming procedures are discussed. The present status of fire retardants in rigid urethane foams is reviewed. Applications for the improved foams are given.

Dinner–Dance

Thursday, January 14

7:30 P. M.

GRAND BALLROOM **TICKETS $10.00**

featuring

- *The Bob Kirk 15-piece orchestra*
- *Hawaiian Airs Troupe*
- *Floor Show—9:00-10:30 P.M.*
- *Dancing—10:30 P.M.-Midnight*

Friday, January 15, 1960 • 9:00 to 11:15 A.M.
Concurrent Sessions–20, 21, 22, and 23

Session 20—Grand Ballroom
New Materials—II

Moderator—Dr. Robert L. Patrick, *Continental Can Co., Inc.*

69. **Organo Phosphorous Epoxide Copolymers**—L. M. Kindley, L. P. Glekas, P. E. Ritt, *Melpar, Inc.*

Certain organo-phosphorus compounds have received considerable attention as possible candidates for making high-temperature polymers. Because of the high stability of —P—C and —P = O bonds, it seemed that a program directed toward modification of epoxide resins by incorporation of phosphorus as an integral part of the epoxide molecule would be a fruitful area to explore.

The initial phase of the work included an evaluation of the thermal properties of a number of commercial epoxide resins by thermal gravimetric analysis, differential thermal analysis, and heat of distortion measurements. The experimental procedure for conducting these tests and the results obtained are reported in detail.

The data obtained in the above tests will be compared to that shown for phosphorus epoxide polymers.

70. **Zerlon 150—A Product of Copolymer Chemistry**—A. L. Bird, T. C. Broadwell, *Dow Chemical Co.*

A new copolymer of methyl methacrylate-styrene has been developed which has good heat resistance, outdoor weatherability and light stability. This crystal clear material known as Zerlon 150, is being sold for both injection molding and extrusion.

Many of the advantages of copolymerizing methyl methacrylate and styrene become apparent during the discussion of physical properties and processability. Polymethyl methacrylate has clarity, toughness and the ability to withstand the effects of light and prolonged outdoor weathering. Polystyrene is easy to process, reasonably tough and economical. The best qualities of both have been combined in this copolymer to fill the gap between low cost materials with valuable but limited characteristics and the more expensive plastics with specialized uses. The combined assets of properties, processability, and cost make this copolymer suitable for many applications in the lighting, sign, automotive and appliance industries.

71. **The Impact of Pro-fax on the Injection Molding Market**—R. D. Ullrich, *Hercules Powder Company*

The impact of Pro-fax® on the injection molding market is analyzed by receiving the status of this versatile new material in products in these fields: Closures & containers, housewares, chemical & hospitalware, toys & sports equipment, automotive, appliance, valve & fitting, miscellaneous.

The case history approach is used to illustrate the why's and wherefores of this rapid acceptance in each field. While many specific applications discussed were primarily based on one of the specific distinctive properties of Pro-fax such as its high heat resistance, flex life, or resilience, it will be pointed out that the use usually required not only that but also the excellent profile of hardness, gloss, tensile strength, impact, price, and molding characteristics.

Plastic molders and plastics users will be able to devise many ideas for their own profitable use of Pro-fax from this analysis of successful case histories.

SPE ANTEC

72. **Polypropylene Industrial Fibers**—G. L. McIntyre, W. J. Craven, W. E. Heumann, *Enjay Co.*

Polypropylene monofilaments (3-15 mil diameter) can be used industrially for making rope, webbing, automobile upholstery, and in other applications. Using commercial fiber equipment, the effects of resin physical properties and processing conditions on monofilament properties have been studied. These studies show high density (highly crystalline), low melt index (high molecular weight) polypropylene resins to be most suited to making industrial monofilaments. The inherent fiber-forming properties of these resins are used to best advantage if they are processed at relatively low extrusion temperatures, utilizing a warm quench bath, and orienting the monofilaments of high temperature (300 to 350°F. orientation oven temperature).

Friday, January 15, 1960 • 9:00 to 11:15 A.M.

Session 21—Training Room
Industrial Design & Coloring

Moderator—Joseph Palma, Jr., *Palma-Knapp Associates*

73. **Structural Design with Plastics**—E. Baer, J. R. Knox, T. J. Linton, R. E. Maier, *E. I. du Pont de Nemours & Co., Inc.*

Designing with plastics is similar to designing with metals. However, the physical properties of plastics are more dependent than metals on time and temperature. When the effects of these variables are known, standard engineering formula may be used with confidence for design applications in plastics to provide maximum use of material properties.

This paper is presented in two parts. Part I describes the mechanical properties with emphasis on the effects of time, temperature, strain, and stress level. Properties are discussed on the basis of elastic and yield design criteria. Elastic design is pertinent to applications where limited deformation of the part under load is of prime concern; a "Modulus Accuracy Limit" concept is presented as a means for defining the acceptable limits. Yield design is important when fracture due to large deformation must be prevented.

Part II presents the recommended methods for using the concepts of Part I in plastics design. Illustrations are given which show how the equations which were originally developed for metals design can be properly applied to designing with plastics. The importance of allowing for the time dependence of mechanical properties of plastics is emphasized.

74. **An Aesthetic Approach to Thermoplastics in Architecture, Art & Interior Decoration**—A. G. Winfield, *DeBell & Richardson, Inc.*

"An Aesthetic Approach to Thermoplastics in Architecture, Art and Interior Decorating" is a sequel to "Thermosetting Resins—A Dream Material for the Artist and Architect" which was presented at the 15th ANTEC, and which will be published shortly in both "Architectural Record" and in "Kunststoff-Berater."

The sequel is likewise an illustrated survey (approximately 40 illustrations) of decorative applications—this time in the realm of thermoplastic materials with special emphasis on the methacrylates, styrenes and vinyls.

The paper deals separately with specific areas confined to the architect, the artist and the interior decorator. The interplay in the materials among these artists and craftsmen, however, is aptly shown as the materials are adapted for uses and applications from one group to another.

75. **Coloring Linear Polyethylene**—P. E. Campbell, R. J. Martinovich, T. V. Gay, *Phillips Chemical Co.*

Considerable knowledge on the coloring of low density polyethylene has been gained over the past several years. Where at one time there were more natural colored molded items sold, colored products are now in the majority. When linear polyethylene became available the immediate demand was for colored resin.

The three most popular methods of coloring low density polyethylene resins are (a) dry coloring followed by injection molding, (b) dry coloring followed by extrusion and (c) concentrate blending followed by either injection molding or extrusion. For the maximum benefit to be derived from each method, the variables affecting coloring must be considered. Problems peculiar to each technique will be discussed relative to their use with linear polyethylene. These will include temperature, pressure, equipment modifications and the addition of pigment dispersing aids.

Pigments used in linear polyethylene must be selected carefully, even more so than for low density polyethylene. Due to the high processing temperatures sometimes employed, heat stability is of the utmost importance. Simple screening tests for pigments will be presented and pigment types found suitable for use in linear polyethylene will be listed.

76. **Safety of Colored Plastics Packaging for Food**—G. W. Ingle, *Monsanto Chemical Co.*

A significant feature of plastics materials used for packaging foods is their capacity for color—for purposes of appeal and identification without deception. This advantage in package design could be jeopardized by an inadequate understanding of the implications of the Food Additives Amendment—and the anticipated Color Additives Amendment—of the 1938 Federal Food Drug and Cosmetic Law.

Colorants useful in plastics materials require careful analysis to insure compliance with legal requirements for packages containing food in interstate commerce. The four pigments "generally recognized as safe" provide a very limited variety of desired colors. Certified food colorants are almost always impractical because of excessive cost and grossly inadequate stability under the thermal conditions common to most compounding operations. Inorganic pigments must now be handled as incidental additives under the Food Additives Amendment and require carefully designed extraction tests to measure migration precisely at the very low permissible levels. Organic colorants—dyes, lakes and pigments of coal-tar origin—are presently legal only if migration to contents of the package is "zero" by the best analytical means available, regardless of safety.

Friday, January 15, 1960 • 9:00 to 11:15 A.M.

Session 22—Room 3
Radiation & Missiles

Moderator—Robert F. Ouimette, *Minneapolis-Honeywell Regulator Co.*

77. **Neutron Shielding with Linear Polyethylene**—D. E. Setter, *Phillips Chemical Co.*

The use of high density polyethylene in neutron shielding is currently aiding in the advancement of nuclear pro-

pulsion for aircraft and ships. One of the outstanding features of rigid polyethylene is the ability of slow down neutrons or attenuate them. At the same time pure, high density polyethylene withstands the damaging effect of continued irradiation while providing the physical toughness and higher temperature resistance required.

The outstanding compressive strength, temperature resistance and tolerance of high radiation dosages are the important construction features. The *relaxation* length (attenuation factor), at 3.5 centimeters against 2-3 MEV neutrons, is considerably better than water, concrete and other plastics. MARLEX polyethylene can be molded into slabs or other shapes with heat and pressure. The high hydrogen content per unit volume and structural integrity of rigid polyethylene provide excellent shielding material for mobile reactors or power plants especially where weight and design factors are critical. Portable or movable shields for radiation research and instrumentation can also use rigid polyethylene.

78. **Plastics for Atom Smashers**—J. O. Turner, *Lawrence Radiation Laboratory University of California*

High-energy nuclear accelerators have produced some spectacular advances in man's understanding of the structure of matter. Many plastic materials perform indispensable functions in these machines and their supporting apparatus. Without these materials, many nuclear experiments would have been impossible. Representative examples are pictured and described.

79. **Technical Capabilities & Development in Engineered Missile Hardware**—J. J. Mobilia, D. V. Rosato, *Raytheon Manufacturing Co.*

Many factors can influence the development of reinforced plastic units. This paper will review these factors in regard to specific units such as magnetron covers, rocket motor bodies, electrical transmitters and reflectors, transition ducts, air ducts, servo base plates, electrical gratings, laminated heat and electrical shields, connectors for special environmental mechanical and electrical units, aerodynamic skins, gyro pickoff, nose cone insulators-ablation, etc., H.S.B.R. reflectors, and others. The purpose of the paper will be to review briefly the technical as well as the practical aspects concerning the use of reinforced plastics in these different units. Details will not be provided, since time and probably audience interest would not be sufficient. A discussion on fabrication aspects of some of these units will be included, since the review would emphasize why reinforced plastics was used.

79A **Plastics Technical Evaluation Center**—Harry E. Pebly, Jr., *Ordnance Corps, Picatinny Arsenal, Department of Defense*

Purpose of this presentation is to acquaint the members of SPE with the purpose, functioning and organization of PLASTEC—Plastics Technical Evaluation Center. The basic concept which led to the decision to establish PLASTEC was the need for a source of comprehensive and properly evaluated technical information on plastics technology which would be available to all Government agencies, contractors, and their suppliers. The functions of PLASTEC are to provide a more effective way of getting evaluated and weighted facts to design engineers by providing publications containing extracts of the significant work on specific subjects; by having its technical specialists make frequent personal contacts with technical personnel in Government and industry; and by furnishing prompt replies to inquiries from design engineers.

Friday, January 15, 1960 • 9:00 to 11:15 A.M.

Session 23—Boulevard Room
Rheology

Moderator—Dr. James F. Carley, *Dept. of Chemical Engineering, University of Arizona*

80. **Effect of Hydrostatic Pressure on Polyethylene Melt Rheology**—R. F. Westover, *Bell Telephone Laboratories*

A description is given of the procedure and equipment used for the purpose of studying the effect of hydrostatic pressure upon the capillary flow properties of polymer melts. Flow properties are reported for a low density polyethylene over a wide range of temperatures, die sizes, differential pressures and hydrostatic pressures. Comparisons are made with preliminary studies made upon other polymer systems.

81. **Stress Relaxation and Creep Measurements on Some Thermoplastic Materials**—R. L. Bergen, Jr., W. E. Wolstenholme, *Naugatuck Chemical Co.*

Because of the need for long term engineering data, a program was begun for studying the creep and stress relaxation behavior of plastics.

A flexural stress relaxometer that records the stress loading and relaxation from 0.08 second was developed for studying the stress relaxation of commercial plastics from 23° to 100°C. A four element exponential relaxation equation was found to provide a good fit for the relaxation curves of all the plastics tested.

In addition, a six position tensile creep tester was designed for measuring the creep of plastic materials from 23° to 100°C. Plotting per cent elongation vs. log time, the creep curves at different loads and temperatures could be superimposed, after compensating for the initial elastic response, by shifting the curves along the log time axis.

82. **Cause of Melt Fracture & Its Relation to Extrusion Behavior**—R. M. Schulken, Jr., R. E. Boy, Jr., *Tennessee Eastman Company*

This paper offers a modified theory of viscoelastic flow which considers the energy required to change the viscosity of a non-Newtonian material. The manifestations of this modification are illustrated by a new model for flow.

83. **Melt Flow Properties of Linear Polyethylenes**—A. P. Metzger, C. W. Hamilton, *Battelle Memorial Institute*

To obtain an indication of relative processing ease, flow lengths in a spiral mold were measured for a large number of commercial high density polyethylenes. Certain low density polyethylenes were included for comparison. The results illustrated that measurements made on polymers from the same producer using a single process form a family of curves when flow length is plotted against temperature. However, the range of flow lengths was not as large as expected. Furthermore, the data demonstrated that similar polyethylenes made by different manufacturers using essentially the same process may have entirely different flow characteristics. The results also indicated that some high molecular weight polymers flow more easily than lower molecular weight polyethylenes. It was concluded that flow measurements should be made at shear stress approaching those encountered in processing machines if the results are to be significant.

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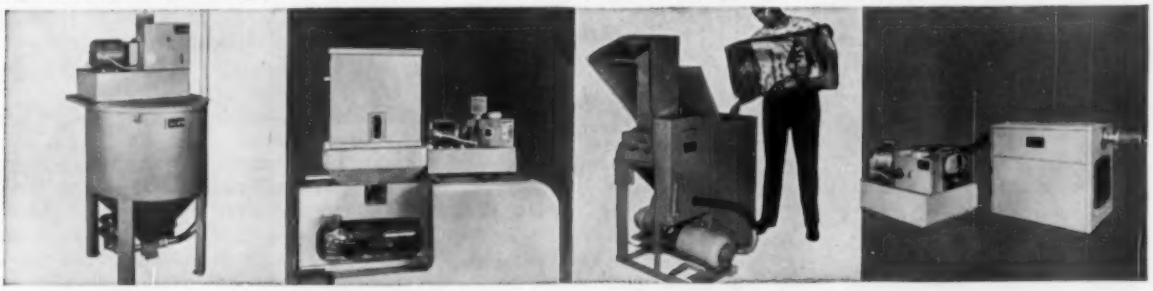

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NATIONAL ACTION

WELCOME TO THE 16th ANTEC . . .

A Message from Franklin L. Fine, Rohm and Haas Co., Chicago
General Chairman, 16th ANTEC

For myself, and for the many committees that have labored so industriously, I take a great deal of pleasure in welcoming you to the Sixteenth Annual Technical Conference of the Society of Plastics Engineers. Here in the hospitable city of Chicago, you will take part in a meeting that has been a year in preparation. The latest information available in our field of endeavor will be presented by men actively engaged in the developments to be discussed.

ANTEC meetings are almost unique in industry. Seldom have so many men given selflessly of their time—with the complete approval and support of their companies—to present papers covering latest developments in their fields. This is true of this ANTEC as it has been of previous ANTECS. The 83 papers that will be presented have been selected from many, the evaluation being accomplished by members of your speakers' committee. In total, these papers actually represent millions of dollars spent in research and development.

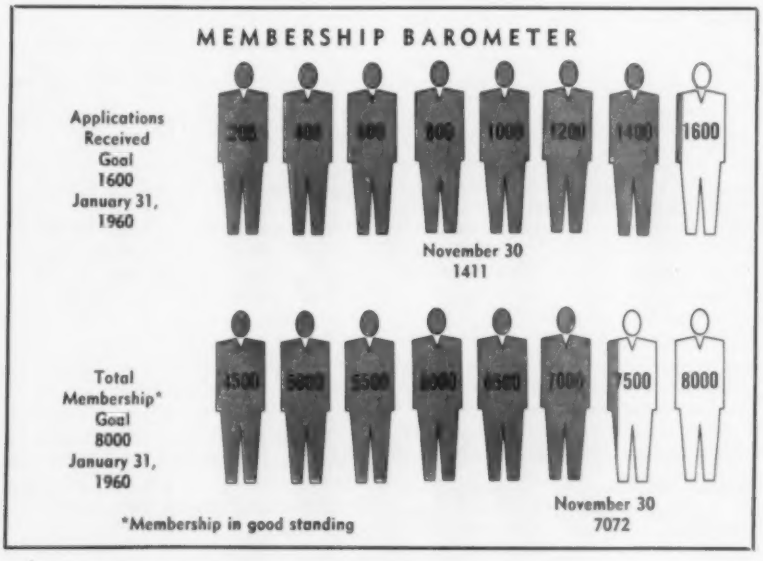
The wonderful thing is that these men—and their companies—are willing to share this information with others in the field in order to help out our entire industry. For it's through the dissemination of information such as this that the plastics industry has enjoyed the fantastic growth of the past 15 years.

The future of our industry rests with the perfection and production of new and better plastic products for an ever-widening circle of applications. How better to gain new information than directly through the men responsible for new developments?

Unlike many meetings, the 16th ANTEC is designed to be a work session—but there is plenty of time set aside for fun . . . at the dinner-dance and following regular meeting and PAG sessions.

Our theme this year is "Professional Achievements and Approaching Opportunities in the Growth of Plastics Engineering." It is our earnest hope that your visit here in Chicago will be time well spent.

Franklin L. Fine
General Chairman
16th ANTEC



edited by **Thomas A. Bissell**
SPE Executive Secretary

TECHNICAL MEETINGS CALENDAR

16th ANTEC

ANNUAL TECHNICAL CONFERENCE—January 12-15, 1960, The Conrad Hilton, Chicago, Ill. Sponsored by the Chicago Section. For more information, wire or phone General Chairman Franklin L. Fine, Rohm & Haas Co., 5750 W. Jarvis Ave., Chicago 31, Ill.

17th ANTEC

ANNUAL TECHNICAL CONFERENCE—January 24-27, 1961, at the Shoreham Hotel, Washington, D. C. The 17th ANTEC is sponsored by the Baltimore-Washington Section. For more information contact General Chairman Dr. Gordon Kline, National Bureau of Standards, Washington, D. C.

1960 RETECS

PLASTICS IN PETROLEUM AND PETROCHEMICAL INDUSTRIES—April 20, North Texas

VINYL PLASTICS—June, Eastern New England

PLASTICS IN BUSINESS MACHINERY—September, 22, 1960, Binghamton

TOOLING FOR THE PLASTICS INDUSTRY—October 19, New York

BLOW MOLDING—November, Newark

Offers of papers in the technical area of each Regional Technical Conference are solicited by each sponsoring Section. Please submit offers and abstracts to Section President indicated below for each RETEC.

Presidents of sponsoring sections are:

North Texas
E. H. Swazey, Lone Star Plastics, P.O. Box 9817, Fort Worth, Tex.

Eastern New England
Gim P. Fong, 9 Maple St., Auburndale, Mass.

Binghamton
Leroy N. Chellis, International Business Machines Corp., Endicott, N. Y.

New York
Herb Weber, Rotuba Extruders Inc., 437 88th St., Brooklyn 9, N. Y.

Newark
Allan G. Serle, 2586 Juliat Place, Union, N. J.

High Speed Testing Symposium

The Second Annual Symposium on High Speed Testing sponsored by Plas-Tech Equipment Corp. will be held at the Somerset Hotel, Boston, Massachusetts, on January 27, 1960.

This is the second in a series of symposia designed to provide a medium for a genuine interchange of information on high speed test techniques, interpretation of data and the significance in application of results.

Tentative Program
Second Annual Symposium on High Speed Testing, Sponsored by Plas-Tech Equipment Corp., Natick, Mass.
Date: January 27, 1960
Co-Chairmen: Professor A. G. H. Dietz, M.I.T., Professor F. R. Eirich, Polytechnic Institute of Brooklyn.

1) "New High Speed Tensile Tester for Polymer Films", Gordon D. Patterson, Jr., (Du Pont).
2) "Smokeless Powder Testing of Polyurethane Foams at Rates of from 1 to 10^6 inches/inch/minute", John W. Jones (Du Pont).
3) "Response of Elastomers, Over a Wide Frequency Range, to a Variety of Forcing Functions", Martin Berger (Esso).
4) "High Speed Testing of Solid Propellants", K. H. Sweeney and Kenneth Bills (Aerojet-General).
5) "Problems Associated with Strain Measurements of Textiles under Impact Loading Conditions", Stanley Backer and Jan Rizek (M.I.T).
6) "Critical Comparison of Moving Bar Impact with Gas Expansion Machines for Dynamic Loading of Metals", Joseph M. Kraft (U.S. Naval Research Laboratory).
7) Subject to be announced, Dr. James N. Brennan (U.S. Navy, Nuclear Ordnance Unit, Albuquerque, New Mexico.

Plastics in Refrigeration Symposium

A Symposium on Plastics in Domestic Refrigeration presented by The Society of the Plastics Industry, Inc., will take place February 1, 1960 in Dallas, Texas before The American Society of Heating, Refrigeration and Air-Conditioning Engineers at its annual National Conference, February 1-4, 1960 at the Baker Hotel.

Improving the Performance and Customer Acceptance of Plastics in Domestic Refrigeration Appliances, will be the theme of the two papers presented by plastics industry representatives and the panel discussion which will follow these talks.

The program of the Plastics Symposium is as follows:

"Should Plastics Be Used in Refrigerators?"

Keynote talk by:
Wayne L. Farley, Vice-President
White Stores, Incorporated
Wichita Falls, Texas
Representing ASHRAE Viewpoints.

"Realistic Properties of Plastics Materials Applied to the Requirements of the Refrigeration Industry"

Talk by:
William E. Brown
The Dow Chemical Company
Midland, Michigan
Representing The Society of the Plastics Industry, Inc.

"Assurance of Satisfactory Performance of Plastics Parts in Refrigeration"

Talk by:
Dale Amos
Amos Molded Plastics Division
Edinburg, Indiana
Representing The Society of the Plastics Indstry, Inc.

Panel Personnel:

The three speakers, Messrs. Farley, Brown, and Amos;
R. B. Akin, E. I. du Pont de Nemours & Co., Inc.;
R. W. Barber, Panelyte Division, St. Regis Paper Co.;
R. H. Carey, Union Carbide Plastics Co.;
L. H. Gustafson, Pro-Phy-Lac-Tic Brush Co.;
C. K. Henry, Celanese Plastics Corp.;
B. M. Nathanson, Monsanto Chemical Co.;
D. P. Shedd, Mobay Chemical Co.;
G. B. Thayer (Moderator), The Dow Chemical Co.

September, 1959, Errata

Six figures were placed over the wrong captions (pp. 792-796). The captions, including figure numbers, should be interchanged as follows:

Caption published under figure	Should be placed under figure
3	4
4	3
5	6
6	5
9	12
12	9

Also in the first and third lines of the second column on page 794 under the heavy line, the temperatures 250°F, and 200°F should read 230°F, and 190°F.

SECTION NEWS

Eastern New England

Four-in-One-Session

D. V. ROSATO

Four subjects were discussed at the November 24th meeting. John A. Kavanagh, Standard Tool Co. spoke on molding machinery at the American Exhibition in Moscow. Robert D. Sackett, Hartig Extruder Co., discussed latest trends in extrusion. J. Fath, Thompson Chemical Co. presented a lecture on Monomeric Epoxy Plasticizers, and Richard Conyne, Rohm and Haas Co. spoke on Polymeric Epoxy Plasticizers.

Ontario

Safety Devices

HAROLD A. SHURE

November meeting of the Ontario Section took place in Toronto, November 19. Mr. Larry Ulmschneider, Chief Engineer, Eastman Kodak Co., N. Y., spoke on "Injection molding, automatic molding on conventional equipment, and the application of safety devices on conventional equipment."

Newark

Instrumentation for Plastics

DAVID SAHUD

The November program was preceded by committee reports which disclosed the following: (1) The Library Committee has instituted a telephone-mail book-lending service; (2) Active PAC's have been formed in Electrical Insulation and Extrusion; and (3) three foreign students—Japanese, Israeli and Indian—have been sent here by their companies to attend the Section-sponsored Plastics Technology Program at the Newark College of Engineering. It was also announced that the Section will hold a RETEC on Blow Molding in November 1960.

The technical program that followed was highly stimulating. W. Blake of C. W. Brabender Instruments, Inc. described the Plastograph, a tool for simultaneously mixing and recording the viscosity of molten resin systems at a wide range of shear rates and temperatures. The instrument appeared to be of considerable interest to the processors and researchers alike and generated considerable discussion.

Mr. Roy Hill of Eastman Chemical Products, Inc., then gave a lucid and highly informative talk on color theory and the use of concentrates in plastics fabrication. Using the color concentration system the procession is able to obtain a wide range of colors at nominal prices.

Milwaukee

Blow Molding

JAMES C. ENGMAN

With the prospect of receiving some long sought-for information on Blow Molding, sixty members and guests of the Milwaukee section gathered to hear Phillips Chemical Company's Don Peters presentation of portions of the paper presented at the recent Los Angeles RETEC.

After the brief but lucid presentation many questions were raised which indicated the varied and enthusiastic interest of plastic converters and application personnel present. Many sample objects were available for viewing which because of their inherent form illustrated both the beneficial aspects and the difficulties encountered in utilization of this process.

Pioneer Valley

Extrusion Forum

ROGER JOHNSTON

The November meeting was an Extrusion Forum, moderated by John Meyers of Foster Grant. Walter Kaghan of Olin-Mathieson Corp. discussed the four techniques of film extrusion—tubular film, air cooled and mandrel cooled and flat film, water cooled and chill roll cooled. The advantages and disadvantages of each method were stated. Once all polyethylene film was made as tubing, but now the chill roll with the best clarity and no water carry-over is growing increasingly popular. Earl Veazey of Dow Chemical Co. talked about extruding polystyrene foam on conventional equipment and production densities of 3-50 lb./cu.ft. There are of course many technical problems but techniques are improving as shown by cups produced on inline vacuum forming of a sandwich of 5 mil. of impact styrene and 10-15 mil. of expanded styrene.

Wire extrusion was the topic of Larry Petzold of Hercules Powder Co. He covered the units required for coating wire and in particular the application of the coat to the wire. Vacuum hopper extrusion was covered by Eugene Heston of National Rubber Machinery. This idea started for eliminating porosity in vinyl with vented extruders but will not eliminate them. Vacuum hoppers eliminate porosity, improve working of material, helps in high humidity and in effect lengthens screw. Surprisingly it was found that a rotary air lock was not needed for the feed. Question time was very informative—one speaker's boss loudly stopping further "information leaks".

Philadelphia

New Plastics

GEORGE R. DeHOFF

On November 24 about 140 members and guests of the Philadelphia Section heard discussions on the properties, processing and application of three new plastics. N. W. Todd spoke about DuPont's new "Teflon" 100 FEP resin. Continuous use at 400°F is practical. S. V. T. Marshall of the Dow Chemical Company discussed their newest member of the plastics family, "Zerlon". This resin, a unique copolymer of styrene and methyl methacrylate, is a transparent material exhibiting properties superior to GP polystyrene.

G. A. Taylor of Hercules Powder Company discussed "Penton", a chlorinated polyether resin which went into commercial production earlier this year. This resin exhibits stability during processing far superior to most chlorinated resins and has found extensive use in the corrosive environments. With "Penton" a completely anticorrosion system, including valves, pipe meters, lined tanks, and pumps is practical.

North Texas Section

Plastics Engineers Planning Regional Technical Conference in Fort Worth

DAVID A. DANIELS

Plans are underway for the annual regional technical conference to be held April 20, 1960, at the Hotel Texas in Fort Worth, Texas, Ray S. Perkins, Southwestern Plastic Pipe Company of Mineral Wells and chairman of the RETEC has announced.

It will be sponsored by the North Texas Section, Society of Plastics Engineers.

The subject is "Plastics in the Petroleum and Chemical Industries". The program will be offered in two concurrent sessions with papers being presented on both surface coatings and plastic structures, covering the most recent developments in both fields.

Program chairman, A. L. Barrier of Barrier Corporation, Mineral Wells, Texas, and R. B. "Pipe" Bender of Tejas Plastics Materials, Fort Worth, said speakers and their topics will be announced later. Perkins urged equipment and corrosion engineers, as well as people engaged in the various phases of the plastics industry, to attend.

Pittsburgh

Business Outlook for 1960

C. A. INFANTE

The second meeting of the Pittsburgh Section of SPE met at the Sherwyn Hotel on Thursday, November 19 for cocktails and dinner. John Parks, President, welcomed several guests from U. S. Steel Corporation, and in his remarks he pointed out that the Pittsburgh Section is the fifth largest section in the United States with a total membership of 117 members.

Speaker for the evening was Mr. Whittney Green, Assistant Manager of Economic Research for the Koppers Company. His remarks centered around the business outlook, particularly for 1960.

Mr. Green made several predictions about the coming year. Among them were the following:

1. There will be a steel contract before the 80-day period is up or a contract will be forthcoming after a very short strike at the end of the 80-day period.
2. 1960 will be 6% to 8% better than '59 would have been had there not been a steel strike.
3. 1960 could well be the best year in our nation's history.
4. There will be a tremendously fast build-up of business during the first six months of '60 in order to fill up the pipe lines of supply, particularly in durable goods.
5. Business spending will be very strong.
6. Plastic consumption in 1960 will hit 6¾ billion pounds as compared to 5⅝ billion pounds in 1959 and 4⅛ billion pounds in 1958.

Baltimore-Washington

Injection Molding Through The Eyes of a Moldmaker

STANLEY P. PROSEN

The November meeting, held at the "Rolling Inn" restaurant, was called to order by Section President George Flanagan. It was attended by 35 members and guests.

Mr. DeFries, Chairman of the Baltimore-Washington RETEC "Stability of Plastics," reported and summarized the progress of the committees.

The speaker of the evening was Ernest J. Csaszar of Newark Tool and Die, who presented a talk on "Injection Molding Through the Eyes of a Moldmaker."

He discussed the role of the moldmaker in the injection molding field and showed that the moldmaker not only makes molds but is cognizant of part design, molding techniques, material technology, and press workings. The roles of the custom molder and the captive molder were discussed. Both types of molders would profit by standardization of mold construction. Also discussed were the merits of hot-runner molds and valve-gating.

Southeast New England Section

Blow Molding Techniques

RAYMOND R. BOTTLEMAN

A record crowd of over ninety members and guests attended the October meeting of the SNE section. Members representing the sections of Eastern N. E., Western N. E., Pioneer Valley, New York, Philadelphia and Cleveland were present.

The speaker for the evening was Leslie J. Kovach, President of the Boston Plastics Machinery Inc. His subject was Blow Molding Techniques, Machines and Economics.

Mr. Kovach pointed out that the packaging field offers a tremendous market for blow molded containers. The packaging field however is only one of many sources for blown items. With a little imagination many articles can successfully be made by blow molding. Some examples are: doll parts and other toys of various types such as bowling pins, bowling balls, baseball bat, pumpkins, etc. Artificial fruits, Xmas ornaments and housewares are other examples where blow molding has been employed.

Although polyethylene is the most frequently used material in blowing, other materials such as polypropylene, acetate, high impact styrene, unplasticized PVC and even nylon are being used for blowing.

There is evidence that the rate of growth of blow molding will be at least equal to and probably greater than either injection molding or extrusion.

Another important fact brought out by Mr. Kovach was the capacity of extruders used in blow molding. For example, a 2½ inch extruder, having a barrel ratio of 20 to 1, and equipped with a 15 horse-power motor, should be figured to extrude 100 pounds of polyethylene per hour. Therefore, a realistic figure on the output of an extruder should be about seven pounds of material per horse-power.

An interesting question and answer period concluded the meeting.

St. Louis

Processing Techniques for Teflon

LYLE R. DEAN

The November meeting of the St. Louis Section was held at the Prime Rib on Clayton Road, November 16, 1959. Thirty members and guests were present.

Otto Wulfert reported on the recent RETEC "Plastics in the Shoe Industry." He read a letter from the Executive Secretary, T. A. Bissell, congratulating the St. Louis Section on a successful RETEC, actually one of the three largest RETECs held to date.

The speaker of the evening was Mr. Frank M. Chapman a sales representative for E. I. du Pont de Nemours & Company. Mr. Chapman explained the difference between "Teflon"* TFE resins and the newer FEP-fluorocarbon resins. Mr. Chapman presented slides to compare the electrical, thermal, and mechanical properties of these two fluorocarbon resins. He pointed out that both of these materials have excellent chemical resistance and weather resistance. He stated that samples of "Teflon" had been exposed for 14 years without showing any effect of weather. The effect of loads, speeds, and temperatures on the frictional properties of these materials were also discussed.

Processing techniques for these two materials were compared and Mr. Chapman showed samples of complex moldings that are now feasible with the FEP polymers, not possible with the TFE fluorocarbons.

Mr. Chapman stated that 60% of the markets for "Teflon" were for electrical and electronic applications.

A group of SPE members and some of their spouses visited the plastics exhibit in Dusseldorf as a group traveling by chartered airplane. They are shown just before take-off from N. Y. Idlewild airport. The group spent the first week of their European stay at the exhibit in Dusseldorf which offered very interesting ideas to most of our members. All out of this group share in the opinion that this exhibit was by far the largest and best in the plastics field. There were exhibited all the German and other European developments in machinery, improvements in the field of screw driven injection molders, blow molding machines, calenders for rigid films and precision instruments. All leading European chemical concerns held huge stands staffed with their sales people, technical service and scientific personnel in order to demonstrate their new raw materials like impact proof vinyl etc. Most inspiring, probably, were the exhibits of European plastics processors, an excellent source of ideas for our domestic market.

As the majority of the participants desired to go again as a group next year, Dr. Neunteufel is planning to organize for members of the SPE and their families two fair visits to Europe in 1960: One for two weeks in July and one for three weeks in August-September. It can also be arranged to go over with the first group and return with the second.

The photo is available to participants ($1.00) Please contact Dr. Heinz Neunteufel, 116-16 Audley St., Kew Gardens 18, L. I., N. Y. (Office tel. EV 3-4350)

SPE Air Tour To Dusseldorf

SPE Members on the trip. C. F. Cutroni, B. J. Danson, L. Goldrosen, G. Gould, S. Grace, W. P. TerHorst, W. B. Jonah, P. Luckino, W. Lukian, M. Maccaferri, R. Marks, A. M. Medor, Jr., M. Mineau, H. Neunteufel, D. Patzsch, J. Reib, F. Ryk, R. Schad, J. Scheidl, G. Ventz, N. S. Waterman, A. G. Weaver, J. Weiss, Jr., P. B. Zazzara.

Oops!

Last month we published pictures of several SPE members who attended the Dusseldorf Plastics Fair. A last minute mixup in captions occurred and Frank Connell, W. R. Grace & Co. was incorrectly identified as Bill Willert, Frank W. Egan & Co. So that our readers will know what Mr. Willert looks like, we are publishing a photo of him at Dusseldorf and also the photo of Mr. Connell taking in the Exhibits.

Frank Connell

Bill Willert

Upper Midwest Section

Designing & Molding With FRP

CHARLES M. SMITH

The November 16 meeting got off to a cool start with a temperature of three degrees above zero in Minneapolis. After a brief administrative meeting, President Don Brekke turned the meeting over to the program chairman, Francis Brown, who introduced Mr. William Houlihan speaker for the evening.

Mr. Houlihan, a graduate of the University of Minnesota with a degree in Mechanical Engineering, is President of Valco Corporation of St. Paul. "Practical Aspects of Designing and Molding with Reinforced Plastics" was the title of his lecture which proved to be very interesting and informative. In addition to sample items molded by Valco, two films were also shown.

Some of the topics discussed were: Design of matched metal dies for reinforced plastics, vacuum bag molding, pre-forming, and plastic and fiber glass materials. Of interest was the fact that, generally speaking, reinforced fiberglass parts used on aircraft are stronger, cheaper, lighter, require less tools and are more resistant to outdoor weathering. A tensile test was shown in one of the films where various materials such as aluminum, stainless steel, magnesium, reinforced fiberglass etc. were heated to around 500°F for thirty minutes. The test bars were then broken in a tensile tester with the reinforced fiberglass requiring the greatest pull to fracture.

Mr. Houlihan felt that the future for reinforced plastics are unlimited in such fields as aircraft, missiles etc.

Central Indiana

Injection Molding Instrumentation

WAYNE NICELY

The November meeting of the Central Indiana Chapter was held at the Continental Hotel in Indianapolis, on Tuesday Nov. 17th.

Mr. Meyrick, President of Industrial Mfg. Co., discussed the theory of mold temperature control. Mr. Ed Finley of Technique Associates described the theory and present development of cylinder temperature control instruments.

Mr. Lyle Dean of E. I. DuPont de Nemours Co. reviewed the research DuPont has done on close tolerance injection molding.

Rochester

Rigid Foams

JOHN T. BENT

The meeting was called to order promptly at 8:00 P.M. After reading the minutes of the last meeting, speakers for the evening were introduced—Mr. Thomas Mayer of the Koppers Company, and Dr. R. G. Nelb of Naugatuck Chemical.

Mr. Mayer discussed rigid foams, especially those made from polystyrene, and reviewed the production, properties and applications of the styrene foams. Dr. Nelb discussed the history, chemical structure, and manufacture of polyurethanes.

Doctor Nelb, our second speaker, confined his talk to the polyurethanes, and discussed their history, chemical structure and manufacture, end uses, and means of fabrication. Doctor Nelb illustrated his lecture with both charts and slides.

After the formal closing of the meeting, an informal question and answer period took place.

Sixty members were in attendance.

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Plastic Prototypes for Automobiles

J. R. LAMPMAN

A very large crowd of interested Section members were on hand to hear the speaker of the evening at our November meeting. Mr. A. Tomchuck, Supervisor of the Plastic Prototype Section of the Body Structures Department—Ford Motor Company—gave a very effective presentation on the use of vacuum forming in the production of visual aids for the different departments of the Company. These aids are sections of automobile bodies planned for production two or three years in the future.

Bridgeport, Conn.

Polymer Structure

K. G. CLARKE

The November meeting of the Connecticut Chapter of SPE was held at the Colonial Restaurant in Hamden. A large turnout heard John R. Ken, Technical Service Representative, of Monsanto's Plastic Division discuss the "Effect of Structure of Thermoplastic on Physical Properties".

Mr. Kent pointed out the ultimate goal of the polymer chemists and physicists is to be able to predict accurately the physical properties of a plastic from its chemical structure alone. The goal has not yet been fully realized but great strides have been made. Many of these were illustrated.

The ever present and essential compromise which raw material suppliers must constantly make between physical properties and fabricability was also discussed by Mr. Kent. The more subtle aspect of structure concerning molecular weight distribution and crystallinity were also covered.

Quebec

Golf Outing

E. W. MAY

The Quebec Section of the Society of Plastics Engineers held their annual Golf Tournament on September 18th. Fifty members and friends descended on the Granby-St. Paul Course for a most enjoyable day. The weatherman more or less cooperated and gave a partly sunny sky and good cool golfing temperatures. The whole day was carefully engineered by John "Tombstone" Bonnett of G.M. Plastics Corporation, ably aided by "Wild Bill" MacInnis of Dow Chemical. Bill Lukian of Lukian Plastics was our jovial starter.

For the second year the Past President's cup was well won by Kenneth Dewar of Dominion Rubber who brought in a neat low gross of 88. Mac Morrison (Industrial Plastic Extrusions) took second low gross with a 91. The first low-net went to Paul Quesnel, (Du Pont) with a 69 while Cy Summerfield of Canadian Plastics Magazine took second low-gross with a 71.

New York

Plastisols & Polypropylene

CHARLES C. ORR

New York VIPAC's October meeting featured two speakers in the second part of its two-part forum on "The Effect of Plasticizers in Processing Vinyls." The program was moderated by Roy L. Kern, Thompson Chemical Co.

Philip G. Whitney, Product Manager—Plastic Material Sales, B. F. Goodrich Chemical Co. discussed "The Effect of Plasticizers on the Processing of Plastisols." Second speaker was Paul D. Sharpe who is senior chemist at Socony Mobil Oil Co.'s technical service laboratories. Mr. Sharpe spoke on the "Effects of Secondary Plasticizers on Processing Vinyl Resins."

New York's general meeting heard William Claypoole, Polypropylene Product Manager, Spencer Chemical Co. speak on "Applications of Polypropylene."

Dr. William Wachs, a management consultant, addressed the entire group on top and middle management's responsibilities for communication throughout a company.

Moderated by Dan Lewis, Robinson, Lewis, & Rubin, Inc., the thermoformers sub-group held the second part of their three-part round table discussions on equipment molds and cost analyses.

At the REPPAC meeting, George T. Morse, Director of Sales, Smooth-On Mfg. Co., talked on "Recent Developments in Plastic Tooling." Dr. Mandell S. Ziegler of Du Pont's Polychemicals Dep't discussed "Acrylic Resins for Reinforced Plastics."

Thirteen Offers . . . . .

"I received thirteen job offers from one classified ad in The SPE Journal's Employment and Service Guide," writes one plastics engineer. If you're "looking," try this employment aid now. SPE members are allowed—free—three non-display insertions in any given calendar year.

Miami Valley Section

Blow Molding and Epoxies Discussed

S. D. MARCEY

The Miami Valley Section, Society of Plastics Engineers, Inc., held their last business meeting of the 1959 calendar year at the Candle Glo Inn in Sharonville, Ohio. Speakers for the evening were Mr. H. R. Bishop, Vice-President of Kautex U.S. Sales Company, Incorporated and Mr. Van Wolf, Chemical Engineer, Cincinnati Milling Machine Company, Cincinnati Ohio. The topic of Mr. Bishop's presentation was "Blow Molding" which, accompanied by slides, presented a detailed picture of the status and problems involved in this rapidly growing area of both foreign and domestic plastic application. Mr. Wolf spoke on "Epoxy Resins–Versatile Adhesives" with regard to a special application in grinding wheels. Using accompanying data slides as an explanation to laboratory evaluations the varying physical properties of epoxy resin modified adhesives were discussed. Both talks were well received by a record crowd of SPE Members. The final get together of the calender year is the annual Christmas party to be held this year at the Biltmore Hotel in Dayton, Ohio.

Cleveland

New Officers Elected

R. L. HUBER

The Cleveland Section of the Society of Plastic Engineers announced at their annual Christmas Dance, December 5th, the new officers for the coming year. These officers are Jack Pecktal, President; Henry Dutot, Vice President; Jerry Clough, Secretary and Paul Zabo; Treasurer. Three new directors were elected by the membership for a three year term and are: Jerry Clough, Ed Haskins, and Barney Wolf. The remaining Directors are: Harold Olson, Don Butler and Monty Forsyth. The Directors also announced plans for a joint golf outing next summer with the Akron Section in the Akron area and a joint Christmas party probably in the Cleveland area. The next meeting of the Society will be held January 18th at the Cleveland Engineering Society and will have two outstanding speakers on the subject of tooling. These gentlemen are Mr. John Slabaugh of Westgate Design Service, Inc. and Mr. W. Wright of Prospect Mold and Die Company.

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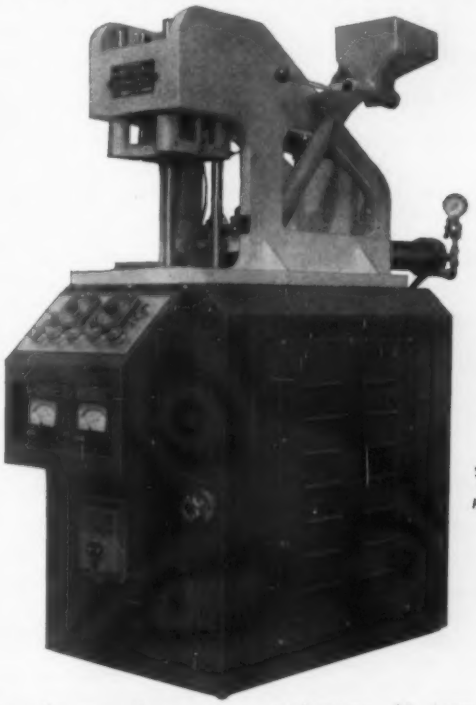

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The regular monthly meeting was held at the Cleveland Scientific Center on November 16 and had as its feature speaker Mr. A. R. "Ren" Morse.

Mr. Morse, the founder of the Cleveland Section of SPE and nationally known throughout the plastic industry as President of Injection Molders Supply Company, spoke on the problems facing the plastic industry; past, present and future. He outlined the growth of the industry and discussed the current trend away from custom molding to proprietary and captive molding and from the latter, the trend toward vertical integration.

The need for injection molding equipment suppliers to keep up with the changes in types of resins, faster cycles, etc., was also outlined.

ABOUT MEMBERS

Rodney H. Morrison has been appointed Sales Engineer for Davis-Standard, Mystic, Conn. Morrison has extensive experience in the plastics field with Celanese Corporation of America, and Du Pont. He is a graduate of Ohio State University.

Thomas E. Daly, Jr. has joined the engineering department of Monsanto Chemical Co.'s Plastics Div. at Springfield, Mass.

Paul J. Skvaril was appointed Manager of West Coast Operations for American Alkyd Industries, Carlstadt, N. J.

John E. Schmitz, was appointed General Manager and Chief Engineer of the recently formed Chemical Division, Electronic Production & Development, Inc. Headquarters are Hawthorne, Calif.

John Delmonte, SPE Administrator for Meetings and Councilman, Southern Calif. Section, was re-elected First Vice Chairman of SPI's Epoxy Resin Formulator's Division.

John W. LaBelle, Assistant to the President of Foster Grant Co., Inc. and Past President of The Society of Plastics Engineers, recently delivered a speech before the Chemical Market Research Association. His speech was entitled Plastics Industry Integration—How Far, How Fast?

Joseph P. Palumbo was appointed manager of the plastics industry division of Nuodex Products Co., Div. of Heyden Chemical Corp. Mr. Palumbo has a B.S. Degree in Chemistry from Columbia.

Gerald D. Minnick appointed director of the new Semi-Conductor Equipment Div. of Conforming Matrix Corp., Toledo.

Harold D. Woodmansee, was promoted to division coordinator of sales warehousing at Monsanto Chemical Co.'s Plastics Div. in Springfield, Mass. Daniel R. Goodfellow, also at Monsanto, was promoted to manager of the Plastics Div. Cleveland Sales Office.

Ernest R. Summers appointed Manager of Product Engineering for Norton Laboratories, Inc. He was formerly with General Electric Co.

E. E. Griesser promoted to Manager of the Union Carbide Technical Service Laboratory, to be located in Geneva, Switzerland. Mr. Griesser formerly was head of the Extruder Products group at Bound Brook, N. J.

Raymond B. Seymour, President, Alcylite Plastics and Chemical Corp., presented a talk entitled Plastics vs. Corrosion to some 20 sections of the National Association of Corrosion Engineers, during 1959.

Harold Kast, has joined Tech-Art Plastics Co., Morristown, N. J. as Product Engineer. Prior to coming to Tech-Art, Mr. Kast was plant manager for Valley Molding Co. in Boonton, N. J.

Donald R. Williams, president of Chippewa Plastics Co., Div. of Rexall Drug and Chemical Co. announced his resignation effective Dec. 1, 1959. Chippewa Plastics was founded by Williams in 1948. Williams will serve as a consultant to the plastics industry.

S. M. T. Hussain, only SPE member from Pakistan, is active in promoting plastics industry in that country. Hussain joined SPE in September 1958. He has developed various types of molding powders using such fillers as Silicates, casein, paper pulp, and jute pulp.

William M. Temple was named manager of government sales for the Urethane Div. of the Dayton Rubber Co. He was formerly associated with Libby Owens Ford Glass Fibers Co.

Arthur Thomas Jr. appointed commodity sales manager of Kralastic materials for Naugatuck Chemical Div. U. S. Rubber Co. He came from Memphis, Tenn. district Sales Office.

Reginald B. Stoops, engineering and marketing consultant, has moved his offices to 52 Hoyt St., Stamford, Conn., from New York City.

William J. Monaha has been named Vice President in charge of sales for the Seamco Chemical Co., Holyoke, Mass.

Jack Sandler promoted to Senior Vice President of Hungerford Plastics Corp. He was formerly Vice President in charge of Injection Molding.

Rodney H. Morrison

Gerald D. Minnick

John E. Schmitz

Harold Kast

PLASTICS AROUND THE WORLD

This month's column has been made possible through the contributions of these abstracters:

Hans Mayer (Industrie Des Plastiques)
Alexander Baczewski (L' officiel des Matières Plastiques)
Alfred Rexer (Plastics)
L. S. Buchoff (Materials in Design Engineering)
Alfred L. Alk (Materie Plastiche and Poliplasti)
Samuel S. Oleesky (Canadian Plastics)

France

INDUSTRIE DES PLASTIQUES

SEPT./OCT. 1959

Polystyrene Film.—Lemaister

Polystyrene film was known as an experimental material for a very long time. However, due to its excessive brittleness no commercial use could be found. This defect can be overcome by orientation which can be accomplished by proper elevation of the process temperature. The physical and chemical values of the resulting product are evaluated and compared to those of acetate and polyethylene film. Fabrication methods and commercial applications are also described.

France

L'OFFICIEL DES MATIÈRES PLASTIQUES

SEPTEMBER 1959

The Polymerization of Styrene—pp 907-909

A short survey of continuous and batch processes as practiced in various countries.

Polystyrene and its Uses—pp 910-917

Good color stable grades of polystyrene are manufactured by suspension polymerization. Injection molding and some of its difficulties are described. Compression and extrusion molding are mentioned briefly. Tables giving the properties of 26 commercially available grades of polystyrene follow.

The Dry Coloring of Plastic Materials—pp 918-922

In many cases the dry coloring of plastics obviates the carrying of masterbatches on the inventory of a molder. The technique does not produce perfect dispersions having a maximum of color strength but it allows substantial savings in the hands of a skilled technician. Formulae for compounds which assist the spreading of the dry colors upon the granules of plastic materials are given for polystyrene, polyethylenen, cellulose acetate, PVC and Nylon. Many colors and standard color matches (e.g. baby blue, ivory etc.) are listed.

Great Britain

PLASTICS

SEPTEMBER 1959

Windsor W. 10 Automatic Fast Cycling Injection Machine—pp 334-336

Pictures and diagram describe the R. H. Windsor 2 oz. shot fully automatic fast cycling injection molding machine.

The Daniels Latymer 80/50 Vacuum Forming Machine—pp 338-339

Detailed drawing and description of a new vacuum forming machine designed to produce formings from sheets of material up to 80 in. by 50 in. in area and up to ½ in. thick.

Heatsealing and High Frequency Welding of Plastics—pp 345-346

The concluding article in a series covers high frequency welding equipment such as continuous welding machines, and power-operated press welders.

Crystalline and Morphological Structures of Polyamides—pp 330-356

A comprehensive article with picture, tables, and bibliography discusses the crystallinity and morphological structures of polyamides or superpolyamides and gives their influence on molded and extruded products.

United States

MATERIALS IN DESIGN ENGINEERING

SEPTEMBER 1959

Adhesive Bonding—J. C. Merriam

This 16-page article outlines properties of adhesives, design of bonded joints, bonding methods and definitions.

OCTOBER 1959

New Reinforced RFE Plastics Resist Cold Flow—Norman L. Greenman

These plastics also offer chemical inertness, low ablation, low friction and good electrical properties. This is achieved by producing a uniform blend of resin and inorganic fibres by the beater addition process. Glass fibre, ceramic fibres and molybdenum disulfide are added to the TFE in various proportions to yield the properties needed for a specific job.

Impregnants for Castings—Robert J. Fabian

Impregnation is used to improve the corrosion resistance of castings and to make them pressure-tight. Impregnants used include polyesters—widely used in critical applications because of low shrinkage after curing and resistance to wide range of corrosive media; and sodium silicate—inexpensive and effective resistance against pressure leakage and corrosion.

Italy

MATERIE PLASTICHE

SEPTEMBER 1959

Coating Polyethylene on Metallic Objects—L. Mangini

In this technique, metallic objects to be coated are preheated and dipped into a fluidized bed of polyethylene powder.

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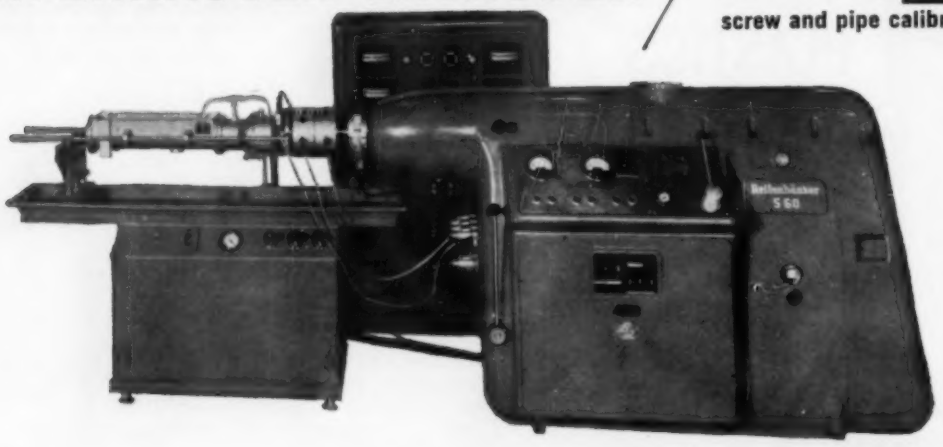

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at the SPE 16th ANNUAL TECHNICAL CONFERENCE . . . . .

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NEW BOOKS

Chemical Analysis of Resin-Based Coating Materials

Edited by C. P. A. Kappelemeier, published by Interscience Publishers, New York, 630 pages, $19.50.

This book is an excellent work on the determination of the constituents of plastic coatings. The authors of the various categories are expert in the fields which they discuss and generally they have done a fine job of presenting the problems and techniques involved in their analytical methods. The majority of resin types and their methods of analysis have been presented. The editor felt that the techniques available for the analysis of silicone resins have not been developed to give reliability of results sufficient to warrant publication at the present time. The polycarbonates, polyethylene, polypropylene, and some of the elastomer resins have not been covered. This writer feels that the chapter dealing with acrylate resins would be more useful if expanded to give more complete coverage. The analytical methods described include the classical gravimetric methods along with many of the latest techniques useful for this type of work. The chapters on complexometric titration and infra-red spectrophotometry were especially good. An unusual and interesting technique was described which makes use of urea and thiourea in extractive crystallization processes. The determinations of solvent and pigment or filler content are generally standard procedures which have been adapted to coating analysis. The water-latex systems have been extensively covered in a separate chapter which also includes the analysis of surfactants and colloids normally found in such systems. These techniques have been described for coating modifications, be adapted to the analysis of normal plastic components.

W. R. Lawton
Nashua Corp.

Vinyl Resins

By W. Mayo Smith. Reinhold Publishing Co., N. Y., 1958, 270 pages. $5.75.

Over two years ago, the Reinhold Publishing Corp. arranged for a series of books on plastic materials and fabrication processes. This series encompasses 15 volumes, most of which have now been published.

This, the seventh of the series, discusses the field of vinyl resins, including polymers of vinyl chloride, alcohol, acetate, pyrollidone, butyral, formal, propionate, carbazole, and vinylidene chloride. Polymerization chemistry, types, properties and fabrication methods are discussed, with a wealth of practical information.

The longest chapter is, appropriately enough, on applications. Emphasis is on poly (vinyl chloride) which is the most versatile of all thermoplastic materials.

It is inevitable that a project of such wide scope and in such a rapidly changing field should include information which is out-of-date by the time of publication. For example, PVC has been superseded by polyethylene far ahead of the predicted date of 1963, as the largest volume resin.

It is possible that vinyls, because of their fantastically wide range of applications, may still show great growth in the near future. Four possible areas of further rapid growth in PVC are rigids, foam, plastisol and flooring. The first two of these have have been disappointing in the past.

There is an interesting chapter on new developments, such as PVP in blood plasma, antibiotics and dyes; radiation; internally-plasticized polymers; and rigid plastisols. PVC Pearls are discussed at great length. The discussion on Delrin is out of place, and perhaps could have been more appropriate in a 16th volume on new plastics.

The book will be of great help to anyone interested in this very complex and dynamic field.

Phillip I. Johnson
Diamond Alkali Co.

Duesseldorf Plastics Exhibition Catalogue

Reprints of the Plastics 1959 Exhibition catalogue are now available again. The new 400 page catalogue contains a reprint of the alphabetical list of exhibitors, an index to classifications, and a list of exhibitors.

Orders will be accepted by the Nordwestdeutsche Ausstellungs-Gesellschaft mbH, Düssoldorf/Germany, Ehrenhof 4.

Toxicology and Applied Pharmacology

Review of the book Toxicology and Applied Pharmacology, published in the November issue of the SPE Journal, was by Dr. Louis C. Barail, Consulting Biochemist and Toxicologist, New York, N.Y.

Looking for a Job

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Employment & Service Guide

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HEAD

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JAN. 12-15TH

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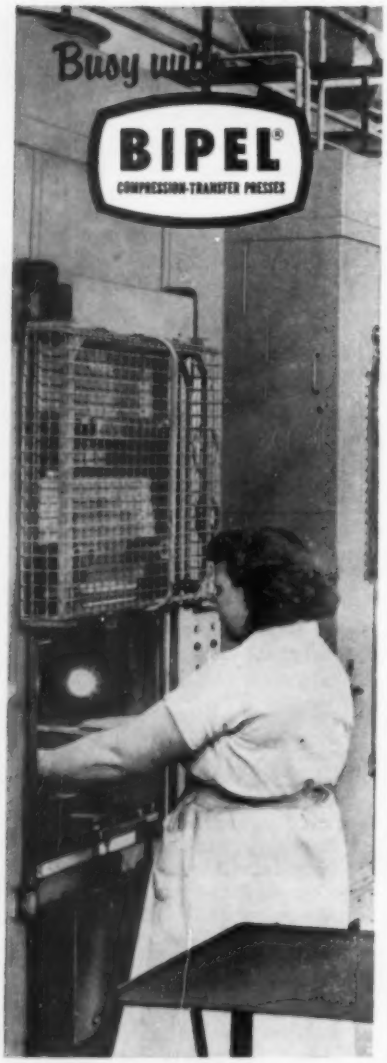

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NEW

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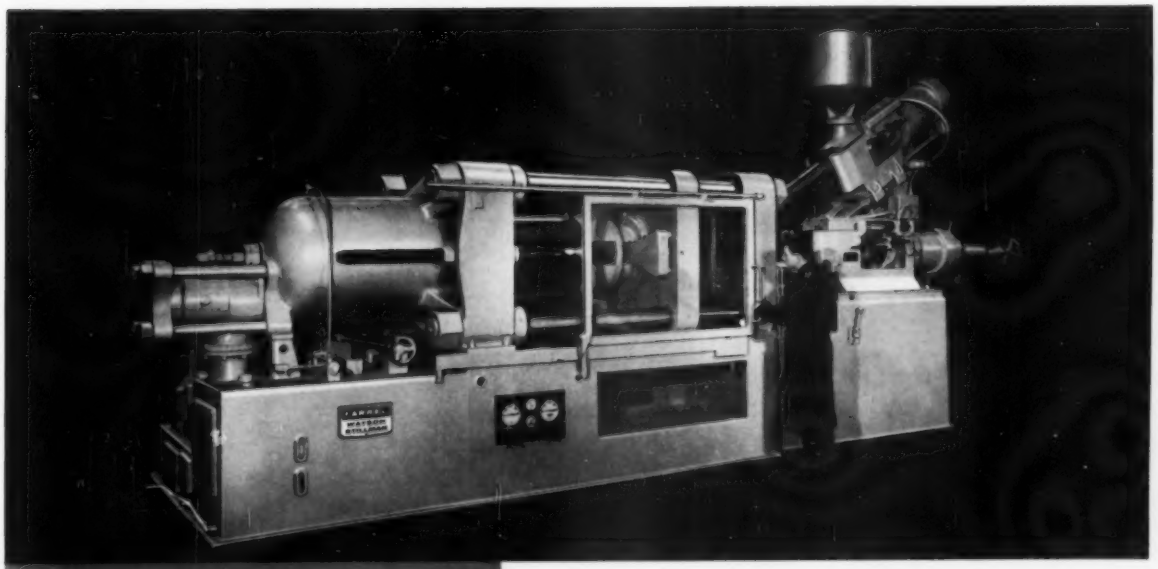

SPECIFICATIONS

Maximum ounces per shot (Styrene)	90
Plasticizing capacity per hour (Styrene)	285 lbs.
Shooting injection rate	1,800 cu. in. per min.
Clamping capacity	650 tons
Maximum Die Sizes	30½" x 48"
Daylight Opening	54"
Clamping Stroke	30"

(Booster system available for higher injection rates)

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